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A SURVEY ON THE CONTENT BELIEFS OF PROFESSORS TEACHING ORGANIC CHEMISTRY

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STRUCTURED ABSTRACT

Background: The content beliefs of preservice chemistry teachers on the topic of organic chemistry were investigated; their content beliefs depend on their own school days. However, a survey on the content beliefs of their teachers at university was not conducted although those beliefs should influence the teaching at university.

Purpose: The content beliefs of university professors on the topic organic chemistry should be investigated in order to gain insights on those beliefs. It can be assumed that those beliefs are fundamental for the organization of courses and lectures for students.

Sample/Setting: 271 professors (all professors teaching organic chemistry in Germany) were invited; 22.9 % participated, but only 18.8 % completed the questionnaire. Only these results were used for the discussion of the survey.

Design Methods: An online questionnaire was developed. This consisted of closed and open items on the topics and concepts of organic chemistry. The data of the questionnaire were transferred to SPSS. For the answers to the items that were rated with the Likert scale, frequencies were calculated. The answers to the open questions were summarized using the method of qualitative content analysis.

Results: Most topics were rated as being important for students at school or at university. Unfortunately, the concepts were rated less high than the topics. Whether this indicates that the professors focus more on topics than on concepts in their lectures should be investigated in another study.

Conclusions/Implications for classroom practice and future research: The use and importance of concepts on organic chemistry in teaching should be investigated.

Keywords: *content beliefs, teacher education, organic chemistry*

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1 INTRODUCTION

The topics dealt with in chemistry lessons at German schools are recommended by the KMK (Kultusministerkonferenz – conference of the ministers for the arts and culture – also responsible for education) (KMK, 2004). The KMK also recommends topics for teacher education to ensure equal standards in Germany (KMK, 2019). However, the exact content of the topics and the teaching methods used are the teachers' responsibility. Professors at university have even more freedom in their teaching; they can choose what they want to teach their students. The content beliefs of chemistry professors are unknown.

Preservice chemistry teachers' content beliefs depend on their own school days; they rated tasks on organic chemistry as relevant if they knew the content from their own lessons at school (Hermanns, 2020). Because university studies are the most important learning opportunity for gaining content knowledge (Kleickmann et al., 2013), the content beliefs of professors who teach at university are of interest for educational research. A survey on the content beliefs of German and Austrian professors on the topic of organic chemistry for future chemistry teachers was therefore conducted.

2 RESEARCH BACKGROUND

Teachers' thought processes have been categorized into three fundamental types: teacher planning, teachers' interactive thoughts and decisions, and teachers' theories and beliefs (Clark and Peterson, 1986). Shulman (1986) defined three dimensions of teachers' knowledge that are important for the teaching process: subject-matter content knowledge, pedagogical content knowledge and curricular knowledge. The research on teaching and learning has shifted from observable teacher behaviour with student achievement to a focus on teachers' thinking, beliefs, planning and decision-making processes (Fang, 1996). The influence of the value teachers attribute to the teaching task and the personal beliefs of the teachers about teaching was evaluated by Fischer and Hänze (2020). The value of teaching correlates with a more constructivist approach of students' education.

Content knowledge is defined by Grossman, Wilson and Shulman (1989) as "knowledge that represents the facts, procedure, and concepts of a discipline as well as beliefs about the subject". Between knowledge and beliefs there is an interactive relationship (Mansour, 2008). Shulman (1986) concluded that teachers' beliefs come from four sources with accumulated content knowledge being one of them. There are two types of belief structures: one is associated with the beliefs about the curriculum and the other with the beliefs about student-centered education (Van Driel, Bulte and Verloop, 2007).

Although many curricula and lectures at university are designed following the topics in organic chemistry, for example starting with alkanes, alkenes etc., new ideas for teaching chemistry at university have been developed. Those newly designed curricula don't focus on the topics, but on core ideas or concepts. Stowe, Herrington, McKay and Cooper (2019) use in their HS-CLUE concept the development of interconnected progressions of core ideas, as for example structure-property relationships. The focus on "teaching how we think instead of what we know" was stated by Talanquer and Pollard (2010). They propose the meaningful learning of central ideas.

Concepts in organic chemistry as for example structure-property relationships were therefore also part of our survey.

2.1 Research questions

This study investigates the following RQs:

1) How do the professors rate the topics for future teachers?

2) How does the rating of these topics compare to the recommendations of the KMK?

3) How do the chemistry professors rate the importance of the topics for the general education of students at school vs. as preparation for their university studies on STEM subjects?

4) How does the rating of topics compare with the rating of concepts?

In addition to these research questions, the answers to the open questions regarding the importance of topics or concepts, will be discussed below.

3 METHODS AND DATA

For the survey a questionnaire was developed (Appendix 1). This questionnaire was then designed with the software QUAMP for use as an online tool. All chemistry professors in the field of "organic chemistry" at German universities (and a few from Austrian universities) received an e-mail with the invitation to participate in our survey. This e-mail also included the link to the online survey. In total 271 professors received an invitation; 62 participated (22.9 %) and 51 completed the questionnaire (18.8%). Only the latter were used for the survey. The questionnaire consists of two parts. In the first part, the professors named the federal state where they are currently working. Three federal states (Hamburg, Mecklenburg-Western Pomerania, Saxony-Anhalt) were not represented. The second part consists of closed and open items on the topics and concepts of organic chemistry. The topics and concepts were taken from the curricula of the federal states in Germany and from the KMK recommendations (KMK, 2004). The KMK recommendations for chemistry at school consist of competences on the topics content knowledge, scientific enquiry, communication and evaluation. Several examples for tasks that are suitable for achieving those competences are included as well. Which topics are part of the curriculum is decided by each federal state independently. A survey on the curricula of all federal states on the topic of organic chemistry by Hermanns and Keller (2019) discusses these differences.

The professors rated the importance of the topics for the general education of students at school, for their preparation for university studies on a STEM (Science, Technology, Engineering, Mathematics) subject or for future chemistry teachers. These closed items were rated with a four-item Likert scale. The professors could select either "strongly disagree", "disagree", "agree" or "strongly agree", using the forced-choice method by removing the neutral option ("neither agree nor disagree") (Allen and Seaman, 2007). The open question asked if there were topics and concepts that were missing in the summary.

The data of the questionnaires were transferred from QUAMP to SPSS. For the answers to the items that were rated with the Likert scale, frequencies were calculated. The answers to the open questions were summarized according to Kuckartz (2016) using the method of qualitative content analysis. Some topics were named, as for example "aromaticity", that are already included in a topic of our questionnaire (here: aromatic carbohydrates). Those topics and topics that are mostly not part of an organic chemistry curriculum were not included in the summary. The excerpts used for this paper were translated from German to English.

4 RESULTS

The frequencies of the answers on all items are shown in tables 1 and 2. Table 1 consists of the topics for all three groups. Table 2 shows the summary of the answers to the open questions.

Tab. 1. Topics for the general education of students at school.

Topic/ Concept	General education of students at school	Preparation of students at school for	For future chemistry teachers

		university studies on STEM subjects	
aldehydes	1: 0.0 % 2: 9.8 % 3: 45.1 % 4: 43.1 % 0: 2.0 %	1: 0.0 % 2: 3.9 % 3: 33.3 % 4: 62.7 %	1: 0.0 % 2: 0.0 % 3: 7.8 % 4: 92.2 %
alkanes	1: 0.0 % 2: 2.0 % 3: 21.6 % 4: 76.5 %	1: 0.0 % 2: 3.9 % 3: 27.5 % 4: 68.6 %	1: 0.0 % 2: 0.0 % 3: 3.9 % 4: 96.1 %
carboxylic acids	1: 0.0 % 2: 2.0 % 3: 33.3 % 4: 60.8 % 0: 3.9 %	1: 2.0 % 2: 3.9 % 3: 27.5 % 4: 66.7 %	1: 0.0 % 2: 0.0 % 3: 11.8 % 4: 88.2 %
alkenes	1: 0.0 % 2: 0.0 % 3: 37.3 % 4: 62.7 %	1: 0.0 % 2: 3.9 % 3: 25.5 % 4: 70.6 %	1: 0.0 % 2: 0.0 % 3: 5.9 % 4: 92.2 % 0: 2.0 %
alkines	1: 0.0 % 2: 15.7 % 3: 49.0 % 4: 33.3 % 0: 2.0 %	1: 0.0 % 2: 7.8 % 3: 39.2 % 4: 52.9 %	1: 0.0 % 2: 2.0 % 3: 13.7 % 4: 84.3 %
alcohols	1: 0.0 % 2: 0.0 % 3: 19.6 % 4: 78.4 % 0: 2.0 %	1: 0.0 % 2: 3.9 % 3: 25.5 % 4: 70.6 %	1: 0.0 % 2: 0.0 % 3: 3.9 % 4: 96.1 %
amino acids	1: 0.0 % 2: 7.8 % 3: 27.5 % 4: 60.8 % 0: 3.9 %	1: 0.0 % 2: 3.9 % 3: 35.3 % 4: 60.8 %	1: 0.0 % 2: 0.0 % 3: 11.8 % 4: 88.2 %
aromatic compounds	1: 0.0 % 2: 3.9 % 3: 29.4 % 4: 64.7 % 0: 2.0%	1: 2.0 % 2: 5.9 % 3: 25.5 % 4: 66.7 %	1: 0.0 % 2: 2.0 % 3: 5.9 % 4: 92.2 %
chelates	1: 9.8 % 2: 45.1 % 3: 31.4 % 4: 9.8 % 0: 3.9 %	1: 5.9 % 2: 33.3 % 3: 35.3 % 4: 25.5 %	1: 3.9 % 2: 11.8 % 3: 23.5 % 4: 60.8 %
enzymes	1: 2.0 % 2: 19.6 % 3: 37.3 % 4: 37.3 % 0: 3.9 %	1: 0.0 % 2: 29.4 % 3: 31.4 % 4: 39.2 %	1: 0.0 % 2: 7.8 % 3: 21.6 % 4: 70.6 %
ester	1: 0.0 % 2: 3.9 % 3: 39.2 % 4: 56.9 %	1: 0.0 % 2: 3.9 % 3: 27.5 % 4: 68.6 %	1: 0.0 % 2: 0.0 % 3: 5.9 % 4: 94.1 %
ether	1: 0.0 % 2: 11.8 % 3: 41.2 % 4: 45.1 % 0: 2.0 %	1: 0.0 % 2: 7.8 % 3: 35.3 % 4: 54.9 % 0: 2.0 %	1: 0.0 % 2: 2.0 % 3: 11.8 % 4: 86.3 %
dyes	1: 2.0 % 2: 19.6 % 3: 37.3 % 4: 37.3 % 0: 3.9 %	1: 2.0 % 2: 19.6 % 3: 41.2 % 4: 35.3 % 0: 2.0 %	1: 0.0 % 2: 2.0 % 3: 25.5 % 4: 72.5 %
fats	1: 0.0 % 2: 7.8 % 3: 41.2 % 4: 49.0 % 0: 2.0 %	1: 0.0 % 2: 5.9 % 3: 47.1 % 4: 45.1 % 0: 2.0 %	1: 0.0 % 2: 0.0 % 3: 9.8 % 4: 90.2 %
halogen alkanes	1: 0.0 % 2: 13.7 % 3: 47.1 % 4: 35.3 % 0: 3.9 %	1: 0.0 % 2: 9.8 % 3: 31.4 % 4: 56.9 % 0: 2.0 %	1: 0.0 % 2: 2.0 % 3: 15.7 % 4: 82.4 %
ketones	1: 0.0 % 2: 7.8 % 3: 51.0 % 4: 41.2 %	1: 0.0 % 2: 3.9 % 3: 35.3 % 4: 60.8 %	1: 0.0 % 2: 0.0 % 3: 7.8 % 4: 92.2 %
carbohydrates	1: 0.0 % 2: 9.8 % 3: 33.3 % 4: 54.9 % 0: 2.0 %	1: 0.0 % 2: 5.9 % 3: 39.2 % 4: 52.9 % 0: 2.0 %	1: 0.0 % 2: 0.0 % 3: 11.8 % 4: 88.2 %
plastics	1: 0.0 % 2: 9.8 % 3: 33.3 % 4: 51.0 % 0: 5.9 %	1: 2.0 % 2: 11.8 % 3: 39.2 % 4: 45.1 %	1: 0.0 % 2: 2.0 % 3: 19.6 % 4: 78.4 %
pharma-ceuticals	1: 3.9 % 2: 33.3 % 3: 37.3 % 4: 23.5 % 0: 2.0 %	1: 5.9 % 2: 27.5 % 3: 35.3 % 4: 27.5 % 0: 3.9 %	1: 2.0 % 2: 9.8 % 3: 33.3 % 4: 54.9 %
pH indicators	1: 2.0 % 2: 23.5 % 3: 39.2 % 4: 35.3 %	1: 2.0 % 2: 21.6 % 3: 35.3 % 4: 39.2 % 0: 2.0 %	1: 2.0 % 2: 0.0 % 3: 23.5 % 4: 74.5 %
proteins	1: 2.0 % 2: 23.5 % 3: 39.2 % 4: 35.3 %	1: 0.0 % 2: 13.7 % 3: 41.2 % 4: 43.1 % 0: 2.0 %	1: 0.0 % 2: 5.9 % 3: 15.7 % 4: 78.4 %
soaps, surfactants, laundry detergents	1: 0.0 % 2: 9.8 % 3: 41.2 % 4: 45.1 % 0: 3.9 %	1: 0.0 % 2: 19.6 % 3: 43.1 % 4: 37.3 %	1: 0.0 % 2: 2.0 % 3: 19.6 % 4: 78.4 %
silicones, siloxanes	1: 13.7 % 2: 39.2 % 3: 41.2 % 4: 2.0 % 0: 3.9 %	1: 7.8 % 2: 43.1 % 3: 27.5 % 4: 19.6 % 0: 2.0 %	1: 7.8 % 2: 15.7 % 3: 35.3 % 4: 41.2 %
vitamins	1: 3.9 % 2: 21.6 % 3: 51.0 % 4: 21.6 % 0: 2.0 %	1: 5.9 % 2: 29.4 % 3: 33.3 % 4: 31.4 %	1: 2.0 % 2: 7.8 % 3: 25.5 % 4: 64.7 %
substance-particle concept	1: 0.0 % 2: 5.9 % 3: 39.2 % 4: 54.9 %	1: 0.0 % 2: 2.0 % 3: 33.3 % 4: 60.8 % 0: 3.9 %	1: 0.0 % 2: 0.0 % 3: 21.6 % 4: 74.5 % 0: 3.9 %

structure-property concept	1: 2.0 % 2: 3.9 % 3: 33.3 % 4: 60.8 %	1: 0.0 % 2: 5.9 % 3: 27.5 % 4: 62.7 % 0: 3.9 %	1: 0.0 % 2: 5.9 % 3: 11.8 % 4: 78.4 % 0: 3.9 %
reaction mechanisms in organic chemistry	1: 2.0 % 2: 27.5 % 3: 37.3 % 4: 33.3 %	1: 0.0 % 2: 7.8 % 3: 41.2 % 4: 49.0 % 0: 2.0 %	1: 0.0 % 2: 3.9 % 3: 11.8 % 4: 80.4 % 0: 3.9 %

1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree, 0 = no answer

Tab. 2. Summary of the answers to the open questions.

	General education of students at school	Preparation of students at school for university studies on STEM subjects	For future chemistry teachers
Topics	green chemistry, renewable resources, plant protecting agents	green chemistry, renewable resources, plant protecting agents, nanoparti-culate systems, nature of science	green chemistry, hetero-cycles, metal-organic compounds, renewable resources, plant protecting agents, terpenes, nanoparti-culate systems
Concepts	electro-phile-nucleo-phile concept acid-base concept	-	electrophile - nucleophile concept acid-base concept

5 DISCUSSION AND CONCLUSIONS

The results will be discussed below with regard to the four research questions and the answers to the open questions. In the conclusions an outlook on further research is given.

5.1 Research question 1: How do the professors rate the topics for future teachers?

The rating of the topics varies between 76.5 % agreement (for the topic silicones, siloxanes) and 100.0 % (for example for the topic alkanes). For the classical substance classes (for example alkanes, carbohydrates) the agreement is 100.0 % with the exception of alkines, aromatic compounds, ether and halogen alkanes, where the agreement is 98.0 %. For our sample this means that only one professor did not agree that those topics are very important for future teachers. Overall, there seems to be consensus that knowledge on substance classes is very important for future teachers. This corresponds with the usual design of lectures or textbooks on organic chemistry that are organized around substance classes.

Unfortunately, those topics that enable a context-oriented approach in chemistry teaching as for example dyes or pharmaceuticals are rated less high. For these topics, the overall agreement varies between 88.2 % and 98.0 %. However, because those topics are a part of the curricula in many federal states, they should also be a part of the curricula at university.

5.2 Research question 2: How does the rating of these topics compare to the recommendations of the KMK?

The topics of our questionnaire are mostly recommended specifically by the KMK (although the substance classes are summarized under the topic “substance classes” and not listed separately). Only the topics chelates, enzymes, pharmaceuticals, soaps etc., silicones etc. and vitamins are not listed there. We added those topics because they are a part of the curriculum in some of the federal states. The rating for the topics that are specifically recommended lies between 94.1 % and 100 %. The opinion of the majority of the professors is therefore in line with the opinion of the KMK. It should therefore be ensured that the recommended topics are part of the curricula for future chemistry teachers at university. The KMK recommendations that are mostly based on the classical content of courses on organic chemistry, fit well with those courses and therefore with the overall opinion of the professors.

5.3 Research question 3: How do the chemistry professors rate the importance of the topics for the general education of students at school vs. as preparation for their university studies on STEM subjects?

The rating of the topics for the students at school show differences. If the students want to study a STEM subject, the topics are on average rated as being more important (84.2 %) than for the general education of the students (81.9 %). The overall agreement for the topics for the general education varies between 40.9 % (chelates) and 100 % (alcohols). Surprisingly, the rating for topics that are relevant for everyday life as for example dyes and enzymes lies at only 74.6 % and for pharmaceuticals even at only 60.8 %. If the students do not learn important facts on those topics at school, it is possible that they do not have another learning opportunity if they do not study a STEM subject. Therefore, it would be favourable if those topics were a part of the school curriculum (in some federal states this is already the case).

The overall rating for the topics as a preparation for a study on STEM subjects varies between 47.1 (soaps etc.) and 96.1 % (alkanes). It is striking that no topic was rated with 100 %. There seem to be two different argumentations for the role of chemistry lessons at school. On the one hand, the topics are rated as important for studies of STEM subjects, on the other hand, topics which the students do not know from school, can be learned at university.

5.4 Research question 4: How does the rating of topics compare with the rating of concepts?

A study on the use of concepts in the course on organic chemistry (Hermanns and Ermler, 2021) at our university shows that concepts or core ideas are no explicit part of this course. However, the students interviewed in this study (pre-service chemistry teachers) would prefer learning conceptual knowledge on organic chemistry, because on the one hand, they do not want to rely only on rote memorization of the topics and on the other hand, they see the relevance of this knowledge for their future profession.

In this survey the professors of organic chemistry were therefore asked to rate the following three concepts; substance-particle concept, structure-property concept and reaction mechanisms in organic chemistry (Tab. 1). With the exception of the rating for the structure-property concept the rating (agree + strongly agree) for the future chemistry teachers (90.2 – 96.1 %) was higher than for the students at school (70.6 – 94.1 %). Those relatively low agreements with the use of concepts at school is surprising, because the KMK (2004) explicitly name the concepts substance-particle concept and structure-property relationships as part of the curriculum at school (students aged 15-16). The topic reaction mechanisms is named (KMK, 2020) for the *Abitur* (British A-level) in chemistry. This finding can be interpreted in several ways; either the professors have a different opinion as the KMK as to which concepts are important for students at school and therefore rate those concepts as less relevant, or the knowledge on the communication of concepts in organic chemistry is not emphasized enough. This second interpretation is supported by our study (Hermanns and Ermler, 2021) which showed that concepts are not explicitly taught at university.

Lower agreement was found for the concept of reaction mechanisms. The KMK recommend for the *Abitur* the "description of selected reaction mechanisms". In our understanding, if reaction mechanisms are a concept, the students should not only describe mechanisms but propose suitable mechanisms by themselves. This conceptual aspect was most likely not considered by some of the professors (only 70.6 rated agreement). The sole description of given reaction mechanisms is in our opinion not meaningful for learning at school (or at university).

However, it can be concluded that the rating of the concepts is less high than the rating of the topics. The reason can be that the most professors will design their course with a focus on topics and not on concepts. For university teachers who educate pre-service chemistry teachers the agreement of 92.2 % for reaction mechanisms as part of the university studies should be an incentive. Especially, if reaction mechanisms are seen as conceptual knowledge and not as topics that are rote memorised.

5.5 The answers to the open questions

Our topics were summarized after analysing the KMK recommendations and the school curricula of the federal states. Because there are other topics and concepts that could be important, we asked the professors to name topics and concepts that they were missing in our summary. Table 2 shows a summary of the topics. The professors named current and relevant topics in chemistry as for example green chemistry or nanoparticulate systems. Although these topics are not (yet) a part of the curriculum at school, they are of interest for future teachers. Curricula can change and besides the regular chemistry lessons, there are a lot of other learning opportunities at school, as for example additional STEM courses, project weeks or excursions, where these topics are very suitable. This would fit the rating of these topics for students at school.

Two additional concepts were named (each by two professors); the electrophile-nucleophile concept and the acid-base concept. Although the latter is also a part of inorganic chemistry (at school and at university) it should also be a part of organic chemistry. In our opinion, this concept should always integrate inorganic and organic examples. This would support the development of conceptual knowledge. The electrophile-nucleophile concept is essential for the development of reaction mechanisms. Nevertheless, we listed this concept here as a concept that was rated as missing although it is in our opinion already part of the reaction mechanism concept.

5.6 Conclusions and outlook

Because the design of this survey followed the recommendations of the KMK for teacher education, the focus was mainly on topics and not on concepts. As one of the professors remarked, this seems to support the rote memorization of these topics. However, a focus on topics does not mean that teaching and learning also focus solely on topics and not on other competences. The students (at school and at university) would otherwise not achieve the intended competences. For example, future teachers should achieve competences that enable them to structure and link chemical areas. They should therefore know the process of scientific enquiry (KMK, 2019). Such competences can only be gained if the teaching uses a more conceptual approach.

Because of the rating of the concepts and the naming of only two other concepts (by only two professors) it seems that conceptual knowledge and its use in teacher training is not as common as it is desirable. To further investigate this assumption, another survey is therefore needed and in planning.

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REFERENCES

Allen, E. & Seaman, C. (2007). Likert scales and date analyses. *Quality Progress, 7,* 64-65.

Clark, C. M. & Peterson, P. L. (1986). Teachers' thought processes. In: Wittrock, M. C. (Ed) *Handbook of Research on Teaching* (255-96). New York: Macmillan.

Fang, Z. (1996). A review of research on teacher beliefs and practices, *Educational Research*, 38:1, 47-6.

Fischer, E., Hänze, M. (2020). How do university teachers' values and beliefs affect their teaching? *Educational Psychology*, *40*(3), 296-317.

Grossman, P. L., Wilson, S. M. & Shulman, L. S. (1989). Teachers of substance: subject matter knowledge for teaching. In M. C. Reynolds (Ed.), *Knowledge base for the beginning teacher* (23-36). New York: Pergamon.

Hermanns, J. & Keller, D. (2019). School-related content knowledge in organic chemistry - How different school curricula should be considered for the development of tasks, *Progress in Science Education*, *2*(1), 17-27.

Hermanns, J. (2020). Perceived relevance of tasks in organic chemistry by preservice chemistry teachers, *Chemistry Teacher International*, *3*(1), 31-44. https://doi.org/10.1515/cti-2020-0002

Hermanns, J. & Ermler, N. (2021). Why school-related content knowledge for pre-service chemistry teachers should include basic concepts in organic chemistry, *Chemistry Teacher International*. 1-9. https://doi.org/10.1515/cti-2020-0033

Kleickmann, T., Richter, D., Kunter, M., Elsner, J., Besser, M., Kraus, S. & Baumert, J. (2013). Teachers' content knowledge and pedagogical content knowledge: the role of structural differences in teacher education. *Journal of Teacher Education*, *64*(1), 90-106.

Kuckartz, U. (2016), *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung*. [Qualitative content analysis. Methods, practice, computer assistance]. Beltz, Weinheim und Basel, Germany and Switzerland.

Kultusministerkonferenz (2004): https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2004/2004_12_16-Bildungsstandards-Chemie.pdf (accessed August 2020)

Kultusministerkonferenz (2019): https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2008/2008_10_16-Fachprofile-Lehrerbildung.pdf (accessed August 2020)

Kultusministerkonferenz (2020) https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2020/2020_06_18-BildungsstandardsAHR_Chemie.pdf (accessed August 2020)

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching, *Educational Researcher*, 15, 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundation of the new reform. *Harvard Educational Review*, *57*(1), 1-22.

Stowe, R. L., Herrington, D. G., McKay, R. L. & Cooper, M. M. (2019). The impact of core-idea centered instruction on high school students' understanding of structure-property relationships. *Journal of Chemical Education* , *96*(7), 1327-1340.

Talanquer, V. & Pollard, J. (2010). Let's teach how we think instead of what we know. *Chemistry Education Research and Practice, 11*(2), 74-83.

Van Driel, J. H., Bulte, A. M. & Verloop, N. (2007). The relationships between teachers' general beliefs about teaching and learning and their domain specific curricular beliefs. *Learning and Instruction, 17*(2), 156-171.

APPENDIX

Questionnaire

The questionnaire for the survey on topics of organic chemistry at school and at university.

General:

In which federal state are you currently working?

- ☐ Baden-Württemberg
- ☐ Bayern
- ☐ Berlin
- ☐ Brandenburg
- ☐ Bremen
- ☐ Hamburg
- ☐ Hessen
- ☐ Mecklenburg-Vorpommern
- ☐ Niedersachsen
- ☐ Nordrhein-Westfalen
- ☐ Rheinland-Pfalz
- ☐ Saarland
- ☐ Sachsen
- ☐ Sachsen-Anhalt
- ☐ Schleswig-Holstein
- ☐ Thüringen
- ☐ None of the federal states

School or university (for readability: asummary of the three questionnaires):

1) The following topics are…

- for the general education of students at school
- for the preparation of a university study in a STEM subject
- for future chemistry teachers

very important:

Topic	Strongly disagree	Disagree	Agree	Strongly agree
aldehydes				
alkanes				
carboxylic acids				
alkenes				
alkines				
alcohols				
amino acids				
aromatic compounds				
chelates				
enzymes				
ester				
ether				
dyes				
fats				
halogen alkanes				
ketones				
carbohydrates				
Plastics				

Pharmaceuticals
pH indicators
proteins
Soaps, surfactants, laundry detergents
silicones, siloxanes
vitamins

2) The following concepts are…

- for the general education of students at school
- for the preparation of a university study in a STEM subject
- for future chemistry teachers

very important:

Topic	Strongly disagree	Disagree	Agree	Strongly agree
substance-particle concept				
structure-property concept				
reaction mechanisms in organic chemistry				

3) The following topics or concepts are lacking in my opinion: