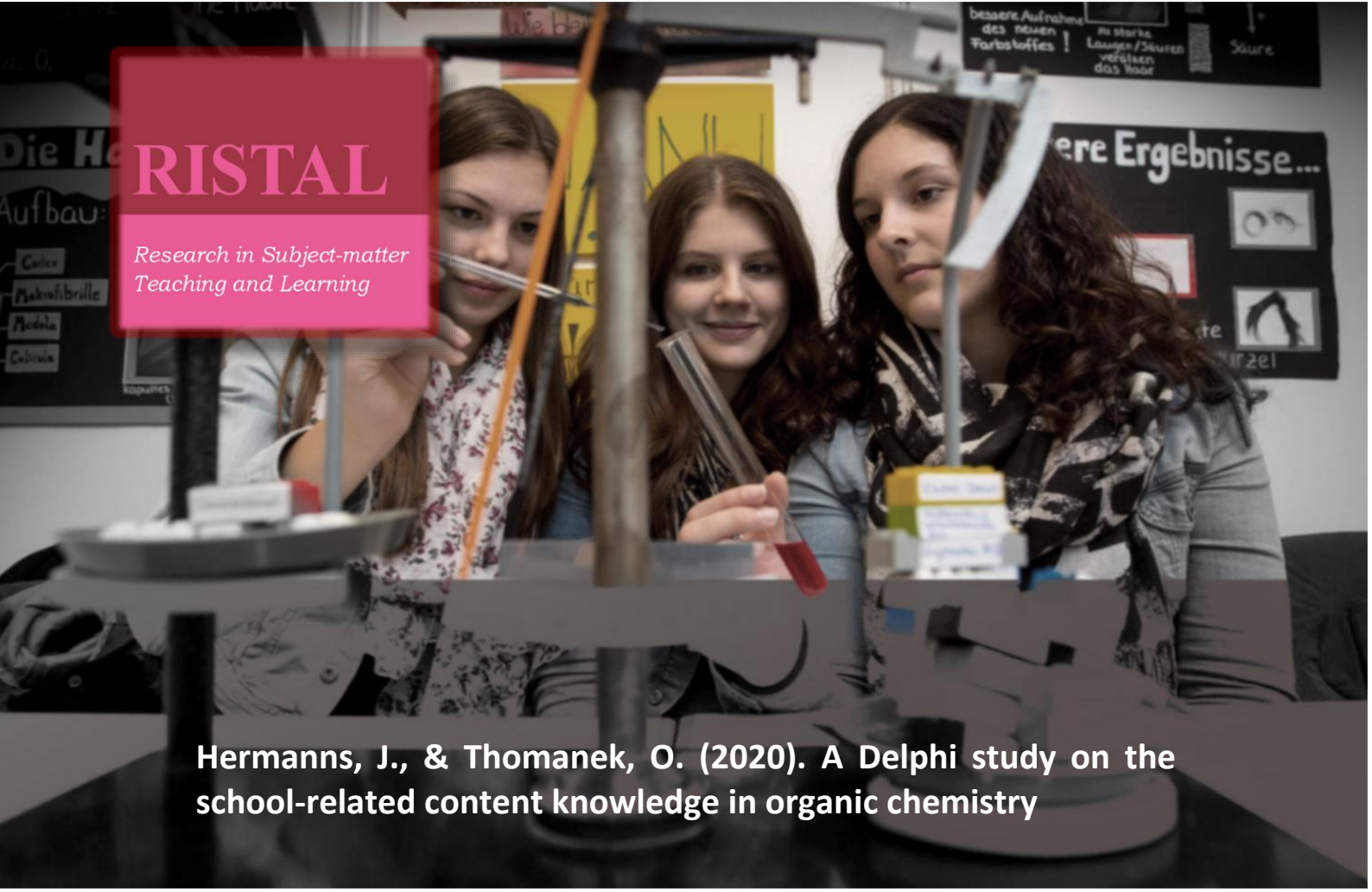

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A Delphi study on the school-related content knowledge in organic chemistry

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Abstract

A Delphi study on the topic "school-related content knowledge in organic chemistry" was conducted in two rounds. National and international experts from the academic and school fields participated. The aim of the study was to investigate what kind of knowledge is practically needed for the future teachers in order to effectively teach in school. The category of the school-related knowledge was recognized as a category providing a sufficient amount of knowledge covering the basics and considering the enhanced conceptual aspects of each topic.

Keywords
science teacher education, school-related content knowledge, Delphi study, organic chemistry

1 Introduction

The professional knowledge of teachers is an important research topic in the program "Qualitätsoffensive Lehrerbildung" which is funded by the Federal German government. The education of teachers as professionals is described by Shulman (1998). He sees all professions, thus including teachers, characterized by six attributes: the obligations of service to others, the understanding of a scholarly or theoretical kind, a domain of skilled performance, the exercise under conditions of unavoidable uncertainty, the need for learning from experience as theory and practice interact and a professional community to monitor quality and aggregate knowledge. Shulman (1986) distinguishes among three categories of teachers` content knowledge: subject matter content knowledge (CK), pedagogical content knowledge (PCK) and curricular knowledge (PK). The CK plays a vital role for the acquisition of PCK (Baumert et al, 2010). The content knowledge is described by Shulman (1986) as *"the amount and organization of knowledge per se in the mind of the teacher"*. As *"knowledge of general concepts, principles and conceptual schemes, together with the detail related to a science topic"* the substantive structure of knowledge was described by Anderson and Clarke (2012). The professional knowledge of mathematics teachers was investigated in the TEDS-M-study (Blömeke, Kaiser and Lehmann, 2010) and in the TEDS-LT-study (Blömeke et al. 2011). The professional knowledge (CK, PCK and PK) of mathematics student teachers was for example investigated here (Buchholtz, Kaiser and Stancel-Piqtak, 2011). Differences in the knowledge of CK and PCK between the different future professions (lower and higher secondary school teachers) of the student teachers were observed. Ball, Thames and Phelps (2008) investigated the content knowledge mathematics teachers need for teaching. They conclude that *"teachers must know the subject they teach. However, just knowing a subject well may not be sufficient for teaching. What seem most important are knowing and being able to use the mathematics required inside the work of teaching".* This leads to the following question: what kind of content knowledge do teachers need? In the STEM-

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subjects therefore several studies were conducted. The COACTIV study developed tests on the content knowledge of mathematics teachers (Kraus et al., 2008). The professional knowledge of science teachers for example was examined in the ProwiN study (Borowski et al., 2010). Moreover, Glowinski and Wendland (2020) conducted an online survey with students who want to become teachers regarding their professional knowledge. One topic was dedicated to the contents of specialist courses. They asked the students whether courses with specialist knowledge should be on a lower level than for students who study the specialist subject. 50.3 % of the bachelor and 46.2 % of the master students voted for a lower level. However, 28.0 % also stated that the actual situation in the courses could remain as it is. Because the wording of the question included "lower level" the students could not answer in any other way. We think that future teachers don't need specialist knowledge on a lower level, but a different kind of knowledge which is suitable for their profession. This is supported by many open statements in the study. The students state very often that there is no apparent connection between the specialist knowledge that is passed on and their future profession as a teacher. Conseqeuntly, Woehlecke et al. (2017) proposed a cross-disciplinary construct of school-related content knowledge and its application in the initial teacher education. They define school-related content knowledge as a combination of conceptual knowledge and skills that are necessary for a thorough understanding of contents relevant to school teaching. It exists, as a category, next to school knowledge and university knowledge. The school-related content knowledge consists of three facets: knowledge on concepts and their application to the respective subject, knowledge of learning processes including subject-specific theories, terminologies, epistemological- and validity principles and knowledge to adapt complexity meaningfully and anticipatorily. This cross-disciplinary construct was used for the design of teaching sessions at university. Massolt and Borowski (2018) describe the development of physics problems for teaching in university physics courses based on the construct of Woehlecke et al. (2017). The physics pre-service teachers perceived those problems as more relevant for their later profession than the regular, quantitative problems also used in the course. Hermanns (2019) describes the development, application and evaluation of tasks in organic chemistry designed on the construct of Woehlecke et al. (2017). Seven criteria for this design are stated: knowledge of organic chemistry, context, competences, discussion, possibility of different answers, language and professional problems. The students rated the tasks that were used in their seminar as relevant for their teaching profession if a school context was used and if they needed competences for solving the task that were related to aspects of their later profession as for example explaining difficult chemical relationships. In this paper we will describe and discuss our Delphi study on the school-related content knowledge in organic chemistry (for upper secondary school) for future chemistry teachers and give an example how this new construct of school-related content knowledge can be evaluated by conducting a Delphi-study.

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2 Delphi-studies in general and in chemistry

Named after the oracle of Delphi, the Delphi method is nowadays used for the estimation of impacts of technology, for the educational planning or for the development of business areas (Häder, 2014). Recently, a Delphi method based on a scientific approach, was used in research and education. It is characterised by an iterative written process that enables to gain the information about one or more insufficient issues by asking experts from the corresponding research fields in anonymous form. A typical Delphi study involves three or more rounds determined by a gradual approach.

Characteristic for Delphi studies is the questioning of experts, mostly by using questionnaires in several rounds. Each round is anonymous. The results from the first round are, as a feedback, returned to the experts. This feedback can be used in the following rounds as a possibility to change one's opinion. The results are evaluated by using several quantitative methods (Bühner, 2011; Kuckartz et al., 2013). In teacher education, Delphi studies are also used. Kunina-Habenicht et al. (2012) used the Delphi method to define which contents in educational sciences are important for teacher education. They interviewed 49 experts who were involved in teacher education at universities and at schools. In the three rounds of their Delphi study consensus regarding the contents was achieved. Gorghiu et al. (2013) conducted a curricular Delphi study, as part of the PROFILES project (see Paiva et al., 2013), with the view to engage various stakeholders in reflecting on contents and aims of science education as well as in outlining aspects and approaches of modern science education. Osborne et al. (2001) used a Delphi study to "*determine the characteristics of scientific enquiry and those aspects of the nature of scientific knowledge that should form an essential component of the school science curriculum*". Critical skills, competencies and qualities for STEM leaders (educational leadership and teacher leaders) were investigated in a Delphi study (Rose, Geesa and Stith, 2019). Charro (2020) conducted a Delphi study to improve the science education of secondary school students in Spain. Students, teachers, educators and scientists participated in this study. As a result, five concepts regarding science education were identified as for example that "*science education should include basic scientific concepts*" or "*science education should relate material and concepts of everyday life*".

An early Delphi study on undergraduate education in chemistry is described by Melton et al. (1977). A main recommendation of the experts in this study is *"that interdisciplinary electives were valuable, feasible, and effective as introductions to other disciplines"*. The Delphi study in chemistry education by Bolte (2002 and 2003a + b) dealt with the question *"which chemistry-related basic education is meaningful and pedagogically desirable for the individual in society today and in near future?"* Students and teachers from school and university and representatives of occupational fields dealing with chemistry were questioned. According to the experts, contents of everyday life and multiperspective attention should characterize what happens in chemistry lessons.

DOI: https://doi.org/10.23770/rt1835

3 Design

3.1 Method

The Delphi technique has been chosen for this study. In comparison to other structural interviews and surveys the Delphi method has the main advantage to focus on the anonymity during answering questions and obtaining feedback and to give the possibility to change the own opinion due to answers of other experts. The anonymous feedback enables to elicit more truthful answers on the one hand and minimize the influence of reputation or authority of experts during the answering of the questions on the other hand (Sahin, 2010). The present study consists of two rounds aimed to achieve a consensus between the experts and a discussion resulting from these. In table 1 the most important details on the design of our Delphi-study are listed and described (a more detailed description of all parts of the study follows below). The main focus lies on the design of a Delphi-study for evaluating new theoretical constructs as for example the school-related content knowledge (Woehlecke et. al, 2017).

DOI: https://doi.org/10.23770/rt1835

Table 1. The design of the Delphi-study for evaluating the construct of the school-related content knowledge exemplary for the topic "organic chemistry"

Part of the study	Challenges	Solutions
Round 1: Expert consultation on the items	The main challenge for designing the items was the wording for the three categories (school knowledge, school-related content knowledge, university knowledge)	Expert consultation; the experts rated the wording of the items. They assigned the wording of the items to all three categories. After this expert rating the items were adjusted accordingly.
Round 1: Participants	The professional function and expertise associated with teaching were the primary criteria. Differences in the educational teaching system within each federal state in Germany (*"Bundesländer"*).	Chemistry professors and professors of chemistry education were contacted. The items contained only content that is part of the curriculum of most federal states.
Round 1: Questionnaire / Items	The wording of the items. It was very difficult to obtain items that represented the three knowledge categories adequately. The scale of the items. Due to differentiate between the three categories it was difficult to formulate short items. Sequence effects should be avoided.	Expert consultation. Use of different sources (school book, different books on university level) with different wording of the content. The items were formulated as short as possible. In the current study, the order of the items was randomized in order to prevent sequence effects.
Procedure (for both rounds)	All questionnaires were send by post. All chemistry professors and professors of chemistry education in Germany were asked to participate. It was crucial for the study that many return their questionnaire.	The post containted the questionnaire and a self-addressed stamped envelope for returning the questionnaire. The procedure and goal of the study was explained in a letter. After a few weeks all participants were reminded and asked to participate by e-mail.
Round 2: Participants	A new group of experts was added: teachers. The teachers should have teaching expertise of at least four years.	Teachers in several federal states were asked to participate and to ask their colleagues that had the sufficient expertise to participate as well.
Round 2: Questionnaire	After the first round several experts suggested to shorten the rather long items. However, the category should remain distinguishable.	Several items were shortened without losing their distinguishable features for the respectable category. To ensure this, the shortened items were discussed with an expert.
Aims	What kind of content knowledge do future teachers need in order to give a school lesson effectively? Is the school-related content knowledge in organic chemistry assessed as a separate category?	The Delphi-study was suitable for answering the research questions.

DOI: https://doi.org/10.23770/rt1835

3.2 Round 1 – Research Questions and aims

Initially, the first round of the current study is characterised by the explorative nature. The experts were asked to provide their professional opinion regarding specific professional knowledge contents submitted in a questionnaire, which consists of 25 questions. The questionnaire was developed by the top down method requiring experts to rate specified given contents according to the corresponding scale.

Consequently, we expect that experts from the different pedagogical institutions (university and school) can differ in their view of specific professional knowledge related contents but nevertheless we assume that a consensus between experts from those institutions can be achieved.

3.2 Round 1 - Participants

The selection of appropriate and qualified expert groups is crucial in a Delphi study. In this study the professional function and expertise associated with teaching were the primary criteria. Furthermore, the local area of the experts was considered due to the organisational differences in the educational teaching system within each federal state in Germany (*"Bundesländer"*).

In the first round of the study one group of experts was selected among chemistry professors, (N=57) both chemistry professors and professors of chemical education nationally and internationally. The participants were contacted und informed about the study by e-mail. The 21 participants (11 chemistry professors and 10 professors of chemical education) were interested in the study and agreed to take part. The participants had four weeks for answering the questionnaire.

3.3 Round 1 - Questionnaire – Items

The questionnaire of the present study consisted of 25 topics that represent organic chemistry contents for the secondary level (for school students aged between 14 to 16 years) as recommended by the KMK (Kultusministerkonferenz – conference of the ministers that are responsible for education, 2004). Each topic has three items that differentiate chemistry specific professional knowledge into three categories: *school knowledge* that describes typical school-based chemistry contents that are usually conveyed during the school lesson. For the formulation of these items the schoolbook "Chemie heute" (Asselborn, Jäckel and Risch, 2009) was used. The second category (*school – related content knowledge*) is characterised by knowledge about concepts and its implementation in the chemistry lesson. The items of this category were formulated with a focus on conceptual knowledge. For this second category the book "Grundlagen der organischen Chemie" (Buddrus and Schmidt, 2015) was used. The school related content knowledge should be especially conceptual knowledge and therefore be suitable for the application of this knowledge on new problems. Such flexible use of knowledge is especially useful and needed in teaching situations. The third category describes *university knowledge* that represents exclusively academic knowledge typically imparted during the lectures and seminars at university. For the formulation of these

DOI: https://doi.org/10.23770/rt1835

items the book “Organische Chemie” (Clayden, Greeves and Warren, 2013) was used. Table 2 shows an example of one topic with its three items. To distinguish between the categories the differences regarding the quality of the knowledge was accentuated.

Table 2. Example of one question inclusively three items (translated from German)

Knowledge category	Item
School knowledge	Alkanes react with oxygen. From a chemical view this is an oxidation reaction. As combustion products carbon dioxide and water are produced.
School related content knowledge	The reaction of alkanes with oxygen is a redox reaction, where the alkanes are oxidized and the oxygen is reduced. When the combustion is complete, the carbon contained reacts to carbon dioxide and the hydrogen contained to water, which is released as steam.
University knowledge	The reaction of alkanes with oxygen is a redox reaction. The alkanes react with oxygen to release energy. The standard combustion enthalpies of the alkanes are higher than those of the alkenes. This is due to the higher number of oxidizable hydrogen atoms in the molecule. Each CH_2-group contributes about 650 kJ/mol.

The formulation of the items for all three knowledge categories turned out to be challenging. On the one hand the items should not be too long and on the other hand the items should represent the knowledge category sufficiently and clear.

Therefore, before the first round of the study all items were rated by four experts (bachelor and master students and one post-doctorate). The rating order was also randomized for the experts. The experts assigned the items to the three categories. For 16 items all experts agreed. There were small differences in nine items. However, only one expert respectively had each a different opinion. Those items were revised. Table 3 shows an overview of all substance categories and topics. The categories have been selected in a way to ensure that they are part of the curricula of most federal states in Germany. As shown by Hermanns and Keller (2019) there are huge differences between these curricula. We wanted to avoid topics that are not part of the curriculum, because those topics could influence the response behaviour of the participants in our Delphi study. In the current study, the order of the items was randomized in order to prevent sequence effects.

DOI: https://doi.org/10.23770/rt1835

Table 3. All substance categories and topics (translated from German)

Substance category	topic
Alkanes	Binding properties of alkanes using methane as an example
	Spatial structure of alkanes using methane as an example
	Combustion of alkanes
	Substitutionreactions of alkanes
	Van-der-Waals interaction
Alkenes	Binding properties of alkenes using ethene as an example
	Isomerism of alkenes
	Addition to the double bond
Alkanols	Class of substances of alcohols (two items)
	Solubility of alcohols
	Boiling temperatures of alcohols
	Oxidation of primary alkanols
Aldehydes	Detection of aldehydes
Carboxylic acids	Class of substances of carboxylic acids
	Reaction of carboxylic acids with alcohols
Fats	Fats – from a chemical point of view
	Properties of fats
Soap	The formation of soaps
	Washing effect of soaps
	Disadvantages of soaps
Carbohydrates	Carbohydrates – from a chemical point of view
Synthetic materials	Synthetic materials – from a chemical point of view
	Polymerisation
	Polycondensation

3.4 Round 1 - Procedure

The questionnaire was distributed via post. A written explanation for the experts how to deal with the questionnaire was added. Initially, the experts completed a socio-demographic questionnaire that included questions about their professional function and geographical area or country of the teaching or research. Furthermore, the experts were asked to rate each item on the basis of three differentiated categories concerning the relevance of each item on the teaching process. In the first category "conducting school lessons" ("Unterrichtsdurchführung") experts should rate the relevance of the given content regarding its relevance for giving chemistry classes. In the second category the experts were asked to rate the given content with regard to its relation to the "basic conceptual understanding of the subject" ("Ein übergeordnetes konzeptuelles Fachverständnis"). Basically, this category enables to determine an overall scientific knowledge that represents diverse thematic contents at the higher conceptual level. Putting this in the context of any school lesson such knowledge enables an expanded explanation of any subject with respect to its conceptual understanding. The third criterion relates to the "part of the teacher education curriculum" ("Teil des Lehramtsstudiums dieses Faches"). This category describes chemistry contents characterised by high scientific level. The experts were asked to determine the relevance of the given contents to this category as well. The experts were able to give their opinion regarding the relevance of given contents to each of three categories by indicating their choice on a 3-ranking scale: indispensable – useful – dispensable. Table 4 outlines one example.

DOI: https://doi.org/10.23770/rt1835

Table 4. Example for the structure of the questionnaire (translated from German)

I consider this content for:	conducting school lessons as:			a basis for the conceptual understanding as:			a part of a teacher education curriculum as:		
Topic:	indispensable	useful	dispensable	indispensable	useful	dispensable	indispensable	useful	dispensable
School knowledge (Content)	□	□	□	□	□	□	□	□	□
School related content knowledge (Content)	□	□	□	□	□	□	□	□	□
University knowledge (Content)	□	□	□	□	□	□	□	□	□

In addition, the experts had the possibility to suggest further contents to each topic that were not mentioned in the given items. These suggestions will not be discussed in this paper.

3.5 Round 2 – Participants

For the second round of the current study an additional group of experts was added: school teachers from different gymnasiums (N=10) from several federal states (*"Bundesländer"*). The teaching expertise (all teachers were chemistry teachers for at least four years) was the decisive criterion for choosing the experts of this group. Furthermore, 36 experts (19 chemistry professors and 17 professors of chemistry education) from the first round were contacted for the second round again.

3.6 Round 2 – Questionnaire

Due to the feedback from the participants after the first round some modifications of the questionnaire were implemented. One critical point was the length of the items. Therefore, the content of some items was revised and considerably reduced without changing the character of each knowledge category. The structure of the questionnaire and the number of topics remained unchanged.

3.7 Round 2 – Procedure

The questionnaire including the explanation of how to answer it as well as the sociodemographic part was distributed via post. The time limit for returning the questionnaire was four weeks.

DOI: https://doi.org/10.23770/rt1835

4 Aim of the study

The aim of our study was to investigate what kind of content knowledge future teachers need in order to give a school lesson effectively. It should also be examined whether the school-related content knowledge in organic chemistry is assessed as a separate category. If it is a separate category, this knowledge should be part of the curriculum at university; learning opportunities should then be provided for the students.

5 Results

5.1 Descriptive statistics - first round

The inquiry of the experts (27 chemistry professors and 30 professors of chemistry education) was carried out by a paper-pencil questionnaire. The 57 experts were invited by e-mail. 11 chemistry professors (41 %) and 10 (33 %) professors of chemistry education completed and returned the questionnaire (Table 5). 19 Participants were from German and two from Austrian universities.

Table 5. Number of respondents by groups for each round

Expert Group	Number invited / participants	
	Round 1	Round 2
Chemistry professors	**27**/11 (41 %)	**19**/8 (42 %)
Professors of chemistry education	**30**/10 (33 %)	**17**/3 (18 %)
Teachers	-	**10**/10 (100 %)

Note. Numbers in bold show the number of invited experts per each round, numbers in plain the number of actual respondents.

5.1.1 Average Deviation Index

The agreement between the experts was calculated on the basis of the Average Deviation Index (ADI) (Burke, Finkelstein and Dusig, 1999; Kunina-Habenicht et al., 2012). The ADI represents the deviations of individual evaluators from the total mean and represents the mean deviation of a group of evaluators from the arithmetic mean of the respective content. An agreement is acceptable, if the ADI is less than the critical value (calculated by the formula A/6). In our study an ADI less than or equal to 0.5 shows an acceptable agreement between the experts. The arithmetic means and ADIs for the contents of all three categories are listed (Table 6). For all categories (school knowledge, school related content knowledge and university knowledge) the agreement was acceptable to high. The agreement on the knowledge that is part of the teacher training at the university was the highest. For the knowledge that is used for conducting school lessons the agreement on the university knowledge was with an ADI of 0.40 just acceptable. The arithmetic mean shows that this knowledge was assessed as useful but not indispensable. However, school knowledge and school related content knowledge were assessed between useful and indispensable. In all three thematic differentiations the

DOI: https://doi.org/10.23770/rt1835

school related content knowledge was recognized as an existing category and assessed between useful and indispensable.

Table 6. Means and ADIs in the first round of the Delphi study in organic chemistry

Thematic differentiation	M	ADI
1. For conducting school lessons		
1.1 School knowledge	2.66	0.21
1.2 School related content knowledge	2.42	0.25
1.3 University knowledge	2.07	0.45
2. As a basis for a conceptual understanding of the subjects		
2.1 School knowledge	2.65	0.26
2.2 School related content knowledge	2.57	0.24
2.3 University knowledge	2.40	0.35
3. As part of the teacher education curriculum		
3.1 School knowledge	2.80	0.21
3.2 School related content knowledge	2.80	0.17
3.3 University knowledge	2.71	0.25

Note. M= mean; ADI – average deviation index (the assessment of the contents was based on a three-ranking scale: 1=dispensable; 2=useful; 3=indispensable).

Furthermore, the group of chemistry professors was compared to the group of professors of chemistry education. The following results are shown in table 7.

Table 7. Means and ADIs for both groups in the first round of the Delphi study in organic chemistry.

Thematic differentiation	M (chemistry professors)	M (professors of chemistry education)	ADI (chemistry professors)	ADI (professors of chemistry education)
1. For conducting school lessons				
1.1 School knowledge	2.70	2.64	0.23	0.20
1.2 School related content knowledge	2.42	2.41	0.27	0.22
1.3 University knowledge	2.16	1.95	0.36	0.44
2. As a basis for a conceptual understanding of the subjects				
2.1 School knowledge	2.73	2.60	0.24	0.31
2.2 School related content knowledge	2.64	2.55	0.25	0.24
2.3 University knowledge	2.50	2.25	0.34	0.39
3. As part of the teacher education curriculum				
3.1 School knowledge	2.85	2.77	0.20	0.22
3.2 School related content knowledge	2.83	2.80	0.20	0.17
3.3 University knowledge	2.80	2.60	0.27	0.37

Note. M= mean; ADI – average deviation index (the assessment of the contents was based on a three-ranking scale: 1=dispensable; 2=useful; 3=indispensable).

The comparison of both groups shows that the professors of chemistry education rated all knowledge categories as less good than the chemistry professors, although all categories were rated as useful or nearly indispensable. This difference is especially clear for the category “university knowledge”: the professors of chemistry education rated this category as only just useful for conducting school lessons. They rated the category highest as part of the teacher education curriculum. There, the rating of the chemistry

DOI: https://doi.org/10.23770/rt1835

professors was also highest. So, both groups find the acquisition of university knowledge useful even if this knowledge is not directly required for teaching at school. The school related content knowledge is rated as especially useful as a basis for a conceptual understanding of the subject and should be part of the university knowledge. Both groups state therefore that the acquisition of this knowledge should occur at university.

5.1.2 Discussion first round

The first round of the current study was aimed to gather professional opinions of experts from the different pedagogical institutions regarding specific professional knowledge related contents with the focus on the school related content knowledge. Concerning this matter, it was expected to achieve a consensus between the experts.

All the 57 experts invited were either chemistry professors or professors of chemistry education; 37 % returned the questionnaire. Relatively low initial responses are often distributed in mail questionnaire studies (Hill and Fowler, 1975). In the initial round a response rate of about 30 % is expected to achieve (Häder, 2000). Thus, the response rate of 37 % provides a solid basis for the opinions diversity on the one hand and shows a great professional interest in the research questions on the other hand. The results received demonstrate an acceptable to high degree of consensus between experts within each category. Despite the locally heterogeneous sample, the experts from the different universities could find out the differences in the contents and rate its importance for teaching organic chemistry at school. Although the focus in teaching is different for both groups, an acceptable to high consensus was reached either in the group of research or didactic specialists.

However, there are some critical points that should be discussed. After the first round of the current study some experts pointed out that it was difficult to differentiate between the categories due to the length of some items. Because of this, the lengths of some items were reduced for the second round of the Delphi study. Secondly, the high degree of consensus could be explained by the homogeneous sample that consisted only of university professors who all deal with organic chemistry contents at an academic level. For this reason, a group of school teachers was invited to take part in the second round of the current study.

5.2 The second round of the Delphi study

5.2.1 Descriptive statistics

The inquiry of the academic experts (N=19 chemistry professors; N=17 professors of chemistry education) and school teachers (N=10) was carried out by a paper-pencil questionnaire. The 46 experts were invited by e-mail. Eight chemistry professors (42 %) and three (18 %) professors of chemistry education completed and returned the questionnaire (Table 4). All teachers (100 %) completed and returned the questionnaire. One questionnaire was filled out incorrectly and could therefore not be considered for the evaluation. Thus, the return rate over all participants during the second round was 46 %.

DOI: https://doi.org/10.23770/rt1835

5.2.2 ADI – second round

To explore the agreement between the experts in the second round we also computed the average deviation index (ADI). The results are presented in Table 8. The mean scores indicate that either the group of academic experts or school teachers rated all contents over all categories mainly as useful or indispensable. Furthermore, the ADIs showed an acceptable to high consensus within each category too. Interestingly, the items of the school knowledge demonstrated the highest degree of consensus in the category regarding the teacher education curriculum. The school related content knowledge was assessed as useful till indispensable. The highest consent was achieved as part of the teacher education curriculum. This was also observed in the first round of the Delphi study as shown in table 6.

Table 8. Means and ADIs for the second round of the Delphi study in organic chemistry

Thematic differentiation	M	ADI
1. For conducting school lessons		
1.1 School knowledge	2.68	0.20
1.2 School related content knowledge	2.35	0.33
1.3 University knowledge	2.00	0.45
2. As a basis for a conceptual understanding of the subjects		
2.1 School knowledge	2.82	0.12
2.2 School related content knowledge	2.67	0.21
2.3 University knowledge	2.38	0.38
3. As part of the teacher education curriculum		
3.1 School knowledge	2.92	0.09
3.2 School related content knowledge	2.87	0.14
3.3 University knowledge	2.78	0.19

Note. M= mean; ADI – average deviation index (the assessment of the contents was based on a three-ranking scale: 1=dispensable; 2=useful; 3=indispensable).

Moreover, the group of scientists (chemistry professors and professors of chemistry education) was compared with the group of school teachers. The means scores over all three categories show that both scientists and teachers groups found the differentiated contents either useful or indispensable (Table 9). The ADIs indicate an acceptable to high consensus between the experts.

DOI: https://doi.org/10.23770/rt1835

Table 9. Means and ADIs for both groups in the second round of the Delphi study in organic chemistry

Thematic differentiation	M (scientists)	M (teachers)	ADI (scientists)	ADI (teachers)
1. For conducting school lessons				
1.1 School knowledge	2.65	2.76	0.19	0.20
1.2 School related content knowledge	2.46	2.23	0.29	0.38
1.3 University knowledge	2.20	1.57	0.41	0.49
2. As a basis for a conceptual understanding of the subjects				
2.1 School knowledge	2.79	2.88	0.16	0.07
2.2 School related content knowledge	2.74	2.58	0.22	0.21
2.3 University knowledge	2.65	2.05	0.38	0.39
3. As part of the teacher education curriculum				
3.1 School knowledge	2.88	2.96	0.11	0.06
3.2 School related content knowledge	2.87	2.88	0.13	0.14
3.3 University knowledge	2.85	2.70	0.19	0.20

Note. M= mean; ADI – average deviation index (the assessment of the contents was based on a three-ranking scale: 1=dispensable; 2=useful; 3=indispensable).

We would particularly like to emphasize that the school teachers rated the university differently for the three thematic differentiations. Although they assessed the university knowledge for conducting school lessons as just useful, they assessed it as part of the teacher education curriculum at university as nearly indispensable. This result contrasts with the results of the study of Glowinski and Wendland (2020). There the students were of the opinion that a lower level of university knowledge would be sufficient for them as future school teachers. The opinion of the school teachers encourages us to talk to the students about this topic. Regarding the school related content knowledge the opinion of the school teachers differed from the scientists: the school teachers rated this knowledge as indispensable as a basis for conceptual understanding and as part of the teacher education curriculum. For conducting school lessons this knowledge category was rated only as useful; the mean was with 2.23 below the 2.46 of the scientists. However, as part of the teacher education curriculum both groups rated the school related content knowledge as being indispensable almost equally.

5.2.3 Discussion – second round

Due to the feedback after the first round an additional expert group was included with the aim to explore and compare the opinions regarding the specific professional knowledge contents. The questionnaire was revised as well. In order to achieve a reliable and objective evaluation of contents a group of school teachers was invited. Because of their practical experience we expected to receive independent assessments of professionals who use this knowledge in their daily practice. Although the response rate of academic experts was less representative in comparison to the first round, the expert group of teachers showed a great interest and participation. The results show a clear answer tendency that despite the different teaching experience the experts could identify the content related difference between the categories similarly and agreed on its relevance for the teaching process. Moreover, it can be noticed that the agreement between experts was achieved with respect to different contents within each category

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whereas each of them is supposed to show a specificity of knowledge including its conceptional and scientific implementation. Such findings indicate that all items fulfil the qualitative requirements needed for the successful preparation and conduction of school lessons in organic chemistry.

6 Limitations

There are some critical points that should be mentioned. The response rate either in the first or in the second round was less representative as it had been expected. We assume that the extensive format of the study required a considerable amount of time from the experts. Probably due to the time constraints several experts could not complete the questionnaire and share their professional opinion concerning the research question with us. Therefore it might be better to reduce a few topics in general or to focus on one or two topics and formulate items regarding these subjects only.

7 Conclusions and outlook

The aim of our study was to investigate what kind of content knowledge is practically needed for the future teachers in order to give a school lesson effectively. For this reason, we conducted a Delphi study that included two rounds in which we asked the experts from the academic and school fields nationally and internationally. The focus was on the specific content knowledge, in particular on the school related content knowledge. This new construct describes knowledge about concepts and their application in the respective subject, knowledge of learning processes including subject-specific theories, terminologies, epistemological and validity principles and knowledge to adapt complexity meaningfully and anticipatorily (Woehlecke et al., 2017). Moreover, this construct has already been successfully used and validated in different scientific studies (Hermanns, 2019; Massolt and Borowski, 2017; Woehlecke et al., 2017). Using the conceptual structure of this construct the items were formulated including different topics from organic chemistry. In the first round we asked chemistry professors and professors of chemistry educaiton about their opinion regarding the relevance of each item for conducting school lessons, conceptual understanding of the subject and its relevance for the teacher education curriculum. The agreement between the experts was achieved in all three categories whereas each of them differed in its conceptual and practical level. Taking into consideration that the focus of the current study was on school related content knowledge, we can suggest that the conceptual structure of these items represents a suitable and effective thematical pattern needed for the teaching process and teaching education. Due to its thematical depth and semantical variety we suggest that such a category can be very useful for the future teachers. We also assume that the contents formulated on this basis represent the necessary school knowledge on the corresponding level and gives an opportunity to cover either the basics or advanced level of knowledge within each topic. In the second round of our study we expanded our expert group and invited teachers from different federal states. Interestingly, the results of the second round of our study demonstrate the same answer tendency despite of the professional differences between academics and teachers. Due to this, we conclude that the formulation of the items was made correctly and reflects necessary thematical

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contents that are usually required during the chemistry school lessons. Moreover, the category of the school related content knowledge was recognized by teachers as a category providing a sufficient amount of knowledge covering the basics und considering the enhanced conceptual aspects of each topic. The school-related content knowledge is especially useful for the teacher when the students at school should build up conceptual knowledge or apply their knowledge on new contents or in other contexts.

As discussed before, our Delphi study was suitable not only for answering what kind of content knowledge future teachers need, but also for determining that the school-related content knowledge is assessed as a separate category by experts. The focus on three different knowledge categories was very challenging for the method "Delphi-study", because it proved to be difficult to formulate short items. For future research, for example for other teaching subjects or content, this should be a main focus while designing the items. However, in our second round, we showed that it is possible to shorten the items without losing the information on the knowledge category. For our study we invited experts from three domains. As the results show there are some differences between those domains. Especially the group of teachers showed a different rating. The university knowledge was for example rated as less relevant for conducting school lessons and as a basis for a conceptual understanding of the subject. As part of a teacher education curriculum the differences between the group of scientists and the group of teachers was not as big. For future studies we recommend to include all three groups and to use the results of such a study for discussing the results with all groups that participated and with students as their opinion on the relevance of university knowledge is different as shown by Glowinski and Wendland (2020). Such discussions can then for example be used to develop the university studies for future teachers.

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