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Research article

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Perceived relevance of tasks in organic chemistry by preservice chemistry teachers

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Abstract: In this article the development, use and evaluation of tasks in organic chemistry is discussed. These tasks are designed following the concept of school-related content knowledge. In this study the perceived relevance of these new tasks by preservice chemistry teachers was evaluated. Of special interest was the question how new tasks should be designed to be perceived as relevant; are some features of the tasks more suitable than others? To answer all research questions a mixed methods study was conducted. To understand the students' rating of the new tasks by using questionnaires, in addition focus group interviews were conducted. The suitability of these new tasks for use in written exams was also evaluated. The results show that the students perceived the tasks as relevant for their future profession if they included contents of the school curriculum, realistic situations and were personalized. They perceived the new tasks also as relevant for practicing skills in communication and explanations.

Keywords: mixed-methods study; organic chemistry; preservice chemistry teachers; school-related content knowledge; tasks.

Introduction

The professional knowledge of teachers attracts continuous attention in science education. As suggested by Shulman (1986) the professional knowledge of teachers consists of three categories: content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK). CK is conceptualized by Cochran and Jones (1998) as knowledge of subject-specific facts and concepts. What kind of content knowledge prospective science teachers need was investigated in the following years. Loewenberg Ball, Thames, and Phelphs (2008) describe the content knowledge for teaching in answering the question "what makes it special?" They state: "teachers who do not themselves know a subject well are not likely to have the knowledge they need to help students to learn this content." The conceptual map of the content knowledge of teachers should however be refined. Therefore "further work in order to understand the most important dimensions of teachers" is demanded. Anderson and Clark (2012) describe two types of subject matter knowledge that science teachers need: knowledge of science and knowledge about science. One important aspect of content knowledge is the knowledge of concepts. The deep understanding about a certain concept is necessary in order to predict the possibilities of students' prior conceptions and to determine strategies in the classroom (De Jong, Veal, & van Driel, 2002 and Yezierski & Herrington, 2011). The content knowledge of teachers is also a prerequisite for developing teachers' PCK (Shulman, 1986 and Kraus et al., 2008).

The professional knowledge of (prospective) physics teachers was investigated in several studies (for example Riese, 2009; Walzer, Fischer, & Borowski, 2014; Woitkowski, Riese, & Reinhold, 2011). A more detailed

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description of content knowledge is given by Riese (2009). He defined three different levels within the content knowledge of (prospective) physics teachers: school knowledge, deeper knowledge of the school knowledge and university knowledge. School knowledge is defined as the knowledge of the school curriculum, university knowledge as the knowledge that is learned in university courses. The deeper understanding of the school knowledge is defined as “deeper and networked knowledge with regard to the school curriculum”. A hierarchical relation between these three levels has not been proven. Therefore Woitkowski, Riese, & Reinhold (2011) described the CK with three steps instead of levels. They defined deeper knowledge as “knowledge that bridges between the school knowledge and the university knowledge”. What kind of content knowledge secondary mathematics teachers need is described by Dreher, Lindmeier, Heinze, and Niemand (2018). They introduce a school-related content knowledge which describes a profession-specific CK for teaching secondary mathematics concerning interrelations between academic and school mathematics. Various conceptualizations of professional knowledge for teachers of mathematics are reviewed by Neubrand (2018). He states “that a significant part of teachers’ professional knowledge should be devoted to building up specific mathematical knowledge, not sheer instrumental knowledge, but in direct relation to the educational issues a teacher is faced with during teaching”. Sorge, Kröger, Petersen, and Neumann (2019) describe a study on the pre-service physics teachers’ professional knowledge (content, pedagogical content and pedagogical knowledge). Their findings show that in the first years of professional education, pedagogical content knowledge is more closely related with general pedagogical knowledge. In later years however, the pedagogical content knowledge is more closely related to content knowledge.

In the project PSI-Potsdam (Professionalism – School-Placement-Studies – Inclusion) the category school-related content knowledge (SRCK) has been modeled for several subjects by Woehlecke & Massolt et al. (2017). This SRCK has three facets: Knowledge of 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. The SRCK is necessary for a deeper understanding of those contents that are relevant for teaching at school. Massolt and Borowski (2018, 2020) developed applied and evaluated tasks in physics based con the construct SRCK. The tasks describe physics problems and are developed as conceptual problems with school relevance. The application was evaluated with a questionnaire. The students rated the problems with regard to their perceived relevance for their later occupation as a physics teacher. The problems based on SRCK are perceived as more relevant than regular physics problems. The focus on conceptual knowledge should therefore be a way to connect school knowledge and university knowledge in CK courses.

In this paper, the development, application and evaluation of tasks in organic chemistry as a means to gain SRCK in organic chemistry will be discussed.

Content knowledge in chemistry

An intervention to improve preservice chemistry teachers’ content knowledge is described by Wheeldon (2017). It is shown that short preservice training sessions help preservice chemistry teachers to develop content knowledge, when it involves addressing commonly used alternative concepts. This approach offers the opportunity to prevent passing on alternative concepts to the next generation of chemistry students and therefore improves also their future chemical knowledge.

The content knowledge of chemistry teachers working at secondary schools in Germany was the topic of a study by Tepner and Dollny (2014). Chemistry teachers working at secondary schools were asked to complete questionnaires probing their chemistry CK and PCK. The content themes were “structure of atoms and the periodic table”, “chemical bonding” and “chemical reactions using acids and bases”. As a result of their study the authors state “that teachers’ chemistry CK varies according to the type of school in which they work. Teachers not using all tested levels of CK in school every day show limited chemistry CK.” As a further result of the study, the correlation between CK and PCK is relevant. For the university education of prospective chemistry teachers “specific knowledge aspects should be reconsidered and CK immediately interlinked with

PCK as it is needed in school.” Content knowledge in organic chemistry, specifically designed for prospective chemistry teachers, will be discussed below.

Lorentzen, Friedrichs, Ropohl, and Steffensky (2019) describe an intervention study for pre-service chemistry teachers to improve the perceived relevance of academic content knowledge. They developed a specific learning program in the field of physical chemistry. This program was applied as an obligatory course and aimed to connect the academic content knowledge with the school-related content knowledge by structured content knowledge. The results of the evaluation show that pre-service chemistry teachers more likely evaluate the academic course to be relevant for their future profession.

SRCK in organic chemistry

Based on the construct of SRCK as described by Woehlecke & Massolt et al. (2017) several tasks in organic chemistry were developed. Table 1 shows the contents in organic chemistry for the first two facets of the model. The contents of the third facet are adopted from Woehlecke & Massolt et al. because they are general, as for example “knowledge to answer in-depth questions” and therefore also valid for organic chemistry. Those contents however require the knowledge and contents of the first two facets. The recognition of misconceptions for example is only possible if someone himself has technically correct ideas.

For the design of the tasks seven criteria are stated: knowledge of organic chemistry, context, competences, discussion, variable answers, language, and professional problems. Most tasks are situated in a context. As a context typical situation from chemistry lessons at school (exams, experiments, talks, and presentations) and university (problems with contents of lectures) have been selected. In total, 12 tasks were developed; three contained no fictitious persons; nine contained fictitious persons with names such as Peter, Marie or Daniel. Seven contexts were located at school, four at university (for the tasks see supplemental online materials).

Research goals

As described before, the SRCK depicts the deeper understanding of conceptual contents that are relevant for teaching at school. Students should therefore acquire this knowledge during their studies at the university.

Table 1: Contents in organic chemistry for the three facets (after Woehlecke and Massolt et al. 2017).

Knowledge of concepts and their application in the respective subject	Knowledge of learning processes including subject-specific theories, terminologies, epistemological and validity principles	Knowledge to adapt complexity meaningfully and anticipatorily
– Chemical bonding theories – Structure-property relationships – Functional groups – Particle-concept – Donor-acceptor-concept – Chemical equilibrium concept – Reaction mechanisms	– Nature of science with a special focus on organic chemistry – Research-based learning – Application-related learning – Structural formulas (Lewis, zig-zag-notation) – Technical language – IUPAC-nomenclature of organic molecules	– Assessment of necessary prior knowledge and possibilities to build up knowledge – Assessment of the consequences of adapting complexity – Knowledge to answer in-depth questions – Knowledge to identify and analyse the nature of misconceptions or errors – Knowledge of alternative approaches to solving tasks on different complexity levels

Solving tasks designed according to the SRCK-concept in the seminar should provide learning opportunities for this purpose. In order to be effective in learning, the students should recognise the relevance of these tasks for their future profession as a chemistry teacher. As stated by Massolt and Borowski (2018, 2020) physics students perceived the problems based on SRCK as more relevant than "normal" physics problems. We therefore assume that the preservice chemistry students will also perceive the problems based on SRCK as more relevant than traditional tasks.

This led to the following research questions:

(1) Why are the tasks following the SRCK-concept perceived as more relevant for the future profession of the students?
(2) Which features of the tasks following the SRCK-concept are related to the perceived relevance for the future profession of the students?
(3) What is the relationship between the type of knowledge and the perceived relevance of the tasks?
(4) How do students rate the tasks with regard to competences in the field of communication?

As an indicator for the learning effect of the tasks and as a consequence, the learning outcome, the written exams were examined which leads to the following research question:

(5) What characteristics should tasks following the SRCK-concept have to be suitable for their use in written exams and consequently for testing the learning outcome?

Design

The study consists of the following four elements:

The seminar and the development of the tasks

The course "Organic Chemistry I" consists of a lecture and a seminar where the preservice chemistry students solve tasks on the topics covered in the lecture. At the end of the course the students have to pass a written exam. For the seminar two types of tasks are developed: traditional tasks (for an example see Figure 1) and tasks following the SRCK-concept (one problem per seminar) as described earlier (for an example see Figure 2).

Each session four or five traditional and one new task are solved. The tasks developed following the SRCK-concept have to be solved as partner work, because the students must discuss the described problem in order to solve the task; the promotion of the technical language, the ability to communicate and the ability to explain facts are some of the goals of these newly designed tasks. The seminar is evaluated using the online evaluation tool of the university. The online evaluation tool consists of questions regarding the previous knowledge of the students, their estimated competences, quality of the academic teaching, the concept of the seminar, the materials used in the seminar and the overall assessment. For this study all items with regard to the relevance for the future profession of the students were analysed. The students rated the items using a six-item Likert scale. (1 = "very good" till 6 = "very poor").

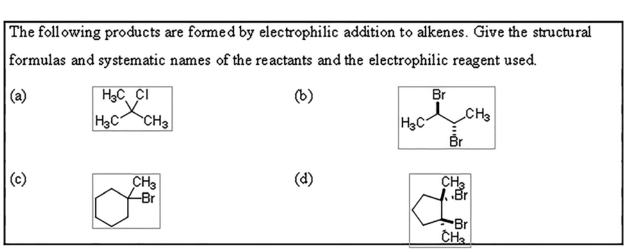

Figure 1: A traditional task.

A chemistry teacher in sixth grade has formulated the following task: "Formulate the electrophilic addition of hydrogen bromide at 2-methyl-2-hexene in separate steps. Name the product systematically after the IUPAC-nomenclature". After returning the written exams there arises unrest in the classroom. Several students are discussing the results of this problem. The teacher asks what they are discussing and gets the following answer from Marie: Jan has given 2-bromo-2-methylhexane as a product and received three points. I have given 3-bromo-2-methylhexane as a product and I didn't get any points for it. But my product is also created by an electrophilic addition!
Help the chemistry teacher in this situation. What mistake did he obviously make in his task?

Figure 2: An example for a task developed following the SRCK-concept.

The questionnaire for the evaluation of the use of the tasks

For the evaluation of the tasks a four-item Likert scale was used (Allen & Seaman, 2007). The students could select either "strongly disagree", "disagree", "agree" or "strongly agree", using the forced-choice method by removing the neutral option ("neither agree nor disagree"). In the seminars the students rated one traditional and one new SRCK-task by comparison. Because the students rated the tasks nearly in every seminar only two tasks in each session were selected. The number of items was also limited to eight. Thus, it was possible to limit the time the students needed for their rating. Table 2 shows the questionnaire.

The focus group interviews

After the evaluation of the tasks of the course 2017–18 it was decided to carry out focus group interviews (see Krueger & Casey, 2014) in order to identify the reasons for the students' answers. The benefit of focus group interviews is the use of group interactions to produce data and insight that would be less accessible without such interaction (Morgan, 1988). Two audio-taped focus group interviews were conducted with five resp. two students (2 f, 5 m). The second group was much smaller due to a strike in public transportation. The students were informed about the study and recruited in the seminar. The students received 20 Euros as compensation for their time invested. The goal of the study and the use of the data were once again explained to the students at the beginning of the focus group interviews; ethical guidelines were followed. The approval of the institutional review board is not required at German universities. During the interviews the students commented on the items of the questionnaire. To ensure anonymity, the students were numbered by a code. They said their code before speaking so that the contributions could be assigned. The transcripts of the focus group interviews were translated to English for this publication.

Table 2: The questionnaire.

	Strongly disagree	Disagree	Agree	Strongly agree
The technical content of the task is important for my future profession.				
The nature of the task is important for my future profession.				
The school context of the task is clearly recognizable.				
In order to complete the task, I have to apply my university expertise.				
In order to complete the task, I have to apply my school knowledge.				
The task promotes my technical language.				
The task promotes my ability to communicate.				
The task promotes my ability to explain facts.				

The written exams

At the end of the course an exam (for 90 min) was written by the students. One exam took place directly after the end of the course; an alternative date for the exam was four months later. For both exams four or five traditional tasks and one task following the SRCK-concept were designed. The difficulties and complexities of all tasks were rated by two experts (one professor for organic chemistry and one PhD in organic chemistry) in order to find two comparable tasks; one traditional task and the task following the SRCK-concept. For both written exams such a pair was identified. The results for these two tasks were compared.

Results and discussion

The seminar was evaluated using the online university tool.

The seminar as a whole is evaluated as very good (1.1). The tasks and the solving of the tasks are also evaluated as very good (1.1 and 1.4). There should therefore be no negative influence through the perception of the seminar as a whole on the results of the study described in this paper. Because the students evaluate the whole seminar as very good, it is most likely that they take the evaluation of the tasks very seriously and will answer to the best of their knowledge.

The results on the use of the different tasks will be discussed below with regard to the five research questions. In the conclusions an outlook on further research is given.

Research question 1: Why are the tasks following the SRCK-concept perceived as more relevant for the future profession of the students?

To answer and discuss this research question first the items "relevance technical content" and "relevance type for future profession" were analysed. The Figures 3 and 4 show the results of the comparison of all tasks for these two items.

The tasks designed following the SRCK-concept are perceived as more relevant for the future profession as a teacher. The difference between the traditional and the new task for the item "relevance type for future profession" is even more pronounced. It seems that the type of the task has elements other than the technical content that the students assess as relevant for their future profession as a teacher. As described before, the tasks should, amongst other things, be suitable for training different communication skills as the use of

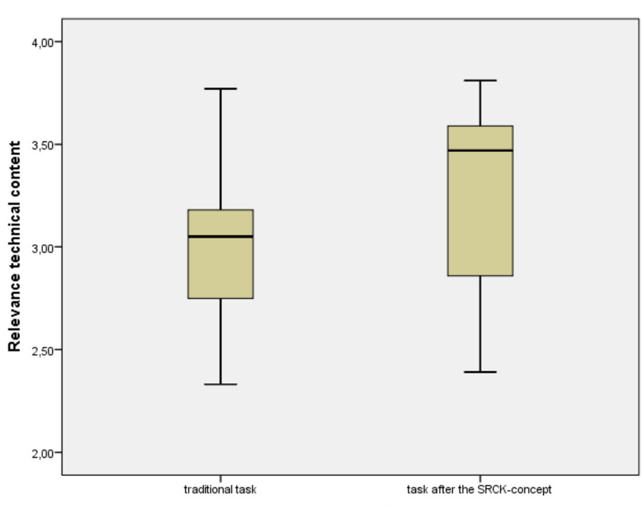

Figure 3: Results of all questionnaires for the item "Relevance technical content".

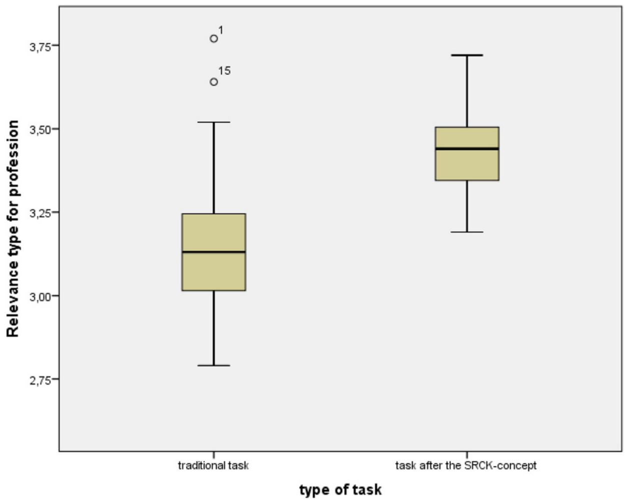

Figure 4: Results of all questionnaires for the item “Relevance type for profession”.

technical language, the ability to communicate and to explain facts. In addition realistic situations from everyday school or university life are described. The students find themselves in these realistic contexts when they solve the problems. That should also be one reason why the type of the tasks is rated even more relevant than their technical content.

To investigate why the students answer like that, focus group interviews were conducted. In answering the item “relevance technical content” the students tried to remember their own school days and what content their chemistry lessons had: *“I try to think back to what the teachers taught us and whether I learned that in school or not”*. As a problem while answering this item the students identified their lack of knowledge concerning the school curriculum. However, in addition to the content, the situation in the school was also considered, e.g. the students ask their teacher a question to this content: *“Or if the students could ask a follow-up question. That I should know that, too”*. The context was also an important argument when answering the item “relevance type of profession”. The school context and with it the possibility to apply knowledge was commented in the interviews: *“Especially in school, application tasks are common”*. The application of knowledge and the opportunity to communicate and train these skills in the tasks was also mentioned often: *“That you really thought about how to explain the technical content to the students”*.

The answers in the focus group interviews suggest that the items “relevance technical content “ and “relevance type for profession” are linked if there is a school context and a content that is part of the school curriculum. This was shown by the Pearson correlations (calculated by using SPSS) (see table 3).

Those tasks are: “Marie”, “Marvin + Leon”, “Laura + Paul”, “Peter + Janina” and “school book”. The correlation is here 0.374 and therefore medium (the correlation is significant at the level of 0.01 (2-sided)). The rating of both items (see table 4) indicate that the students assess the tasks as relevant for their future profession. Because both items influence each other positively, both the school context and the school curriculum content should be considered when developing new tasks.

Table 3: The Pearson correlations for the items “relevance technical content” and “relevance type for profession” for all tasks with a school context and school content ($N = 148$).

	Relevance technical content	Relevance type for profession
Relevance technical content	$r = 1$	$r = 0.374$**
Relevance type for profession	$r = 0.374$**	$r = 1$

**The correlation is significant at the level of 0.01 (2-sided).

To further investigate the relevance of the new tasks, for all items Cohen's d was calculated and an analysis using a two-tailed independent t-test was conducted for the tasks belonging to the category "school content and school context". The statistical data obtained are shown in table 5.

The difference in the rating of the item "relevance technical content" is significant with $p = 0.000$ till 0.014. The relevance of the technical content for the new tasks is perceived significantly better by the students as also shown by the effect size between $d = 0.669$ and 0.117. The rating of the "relevance type of profession" shows an average to good effect size ($d = 0.243 – 0.693$) although it is not perceived as significant as for the item "relevance technical content" with $p = 0.008 – 0.328$. The rating of the item "recognisability of the school context" is also significantly better for the new tasks ($p = 0.000$). This result however is not unexpected: all new tasks investigated have a clear school context. It would have been a surprise if the students had rated these tasks differently. For the development of tasks belonging to the school-related content knowledge, the results of the items "communication" and "explain facts" are also interesting as both items show for some of the news tasks that these are rated significantly better ($p = 0.000$ till 0.881) and show average to good effect sizes ($d = 0.054 – 0.912$). Thus, as intended, the new tasks are perceived as more relevant and give an opportunity to practice skills in communication and the explaining of facts.

Research question 2: Which features of the tasks following the SRCK-concept are related to the perceived relevance for their future profession by the students?

The features "school context" and "school content" are correlated positively as discussed under research question 1. However, there are other features used for the development of the tasks as shown in table 6. In total, six different features are used. The combination of these features amounts to six types of tasks. Table 6 shows the results for the items "relevance technical content" and "relevance type for future profession" for each type.

The relevance types for profession was rated between 3.22 and 3.56, i.e., between agree and strongly agree. The type of the task was always rated as relevant, independent of the content of the task. All tasks are contextualized and have a clear problem that must be solved in partner work. Such tasks seem to be very motivating for the students. The relevance of the technical content however is rated lowest (between agree and disagree) if the content was part of the university curriculum (arithmetic mean 2.39 and 2.91) or if the context was situated at university (arithmetic mean 2.86). It was rated highest if the content is part of the school curriculum, the context is at school and the task is personalized (arithmetic mean 3.66). Non-personalized tasks are rated a bit lower with an arithmetic mean of 3.52. When it is not clear whether the context is at school or at university or somewhere different, the task was rated with 3.77. However, this task ("Hannah") was personalized. The results of the questionnaires suggest that the most important features for the development of tasks are the school curriculum and personalized tasks.

Table 4: The different features for the tasks developed.

Features used in the tasks (The topic is on the school curriculum (1), the topic is on the university curriculum (2), the context is personalized (3), the context is a school context (4), the context is a university context (5) or the context is not clear (6)).	Tasks
2, 4	Claisen
1, 4	Glossary, School book
1, 3, 4	Marie, Marvin + Leon, Laura + Paul, Peter + Janina
1, 3, 5	Luisa + Max
1, 3, 6	Hannah
2, 3, 5	Max + Tim, Daniel, Johanna + Tim

Table 5: Statistical data on the tasks belonging to the category "school content and school context": results of the Mann-Whitney-Test and effect sizes (Cohen's *d*).

Item/Task	Marie $N = 37$	Marvin + Leon $N = 34$	Laura + Paul $N = 32$	Peter + Janina $N = 18$	School book $N = 27$
Relevance technical content	$U = 312.50$ $Z = -4.316$ $p = 0.000$ $d = 1.117$	$U = 401.00$ $Z = -2.449$ $p = 0.014$ $d = 0.669$	$U = 308.00$ $Z = -3.216$ $p = 0.001$ $d = 0.885$	$U = 81.50$ $Z = -2.985$ $p = 0.010$ $d = 0.646$	$U = 226.00$ $Z = -2.561$ $p = 0.010$ $d = 0.715$
Relevance type for profession	$U = 443.00$ $Z = -2{,}869$ $p = 0.004$ $d = 0.531$	$U = 489.00$ $Z = -1.203$ $p = 0.229$ $d = 0.243$	$U = 336.00$ $Z = -2.647$ $p = 0.008$ $d = 0.693$	$U = 118.50$ $Z = -1.507$ $p = 0.171$ $d = 0.546$	U = 312.00 Z = −0.979 $p = 0.328$
Recognizability of the school context	$U = 268.00$ $Z = -4.875$ $p = 0.000$ $d = 1.252$	$U = 305.00$ $Z = -3.600$ $p = 0.000$ $d = 1.012$	$U = 215.00$ $Z = -4.316$ $p = 0.000$ $d = 1.223$	$U = 59.00$ $Z = -3.508$ $p = 0.000$ $d = 1.163$	$U = 120.50$ $Z = -4.497$ $p = 0.000$ $d = 1.515$
Application university knowledge	$U = 619.50$ $Z = -1.033$ $p = 0.302$	$U = 434.00$ $Z = -2.118$ $p = 0.034$	$U = 382.00$ $Z = -2.321$ $p = 0.020$	$U = 124.50$ Z = −1.521 p = 0.239	$U = 206.00$ $Z = -3.187$ $p = 0.001$
Application school knowledge	$U = 648.00$ $Z = -0.409$ $p = 0.682$	$U = 489.50$ $Z = -1.135$ $p = 0.257$	$U = 347.50$ $Z = -2.327$ $p = 0.020$	$U = 129.50$ $Z = -1.088$ $p = 0.308$	$U = 292.50$ $Z = -1.311$ $p = 0.190$
Technical language	$U = 674.50$ $Z = -0.118$ $p = 0.906$	$U = 464.00$ $Z = -1.497$ $p = 0.135$	$U = 449.50$ $Z = -0.926$ $p = 0.355$ $d = 0.193$	$U = 155.00$ $Z = -0.274$ $p = 0.839$	$U = 284.50$ $Z = -1.505$ $p = 0.132$
Communication	$U = 377.50$ $Z = -3.527$ $p = 0.000$ $d = 0.912$	$U = 567.00$ $Z = -0.149$ $p = 0.881$ $d = 0.085$	$U = 361.00$ Z = −2.227 $p = 0.026$ $d = 0.591$	U = 118.50 Z = −1.528 $p = 0.171$ $d = 0.620$	U = 270.50 Z = −1.709 $p = 0.087$ $d = 0.486$
Explain facts	$U = 507.00$ $Z = -2.117$ $p = 0.013$ $d = 0.566$	$U = 530.00$ $Z = -0.710$ $p = 0.478$ $d = 0.182$	$U = 472.50$ $Z = -0.636$ $p = 0.525$ $d = 0.054$	$U = 159.50$ $Z = -0.085$ $p = 0.938$	$U = 330.50$ $Z = -0.676$ $p = 0.499$ $d = 0.205$

Research question 3: What is the relationship between the type of knowledge and the perceived relevance of the tasks?

The evaluation of the first study on the use of the tasks in 2017–18 showed that the standard deviation for the item "In order to complete the task, I have to apply my school knowledge" was relatively high (0.696 – 1.076). During the focus group interviews the students were therefore specifically asked how they define "school knowledge" in distinction from "university knowledge". Statements from the students on the definition of school knowledge are: *"It's what I had in school or what I could explain with my school knowledge". "Everything I learned till my school exam". "The knowledge from school without the knowledge from the university lectures."* As a reason for the relatively high standard deviation the attendance of different schools by our students with their different curricula seems probable, as the following quote shows: "*Our school was an elite STEM-school and I don't know how far ahead we were of the other schools.*" However, the interviews showed that the students distinguish between school knowledge and university knowledge, but that especially the school knowledge was very personal. To answer the research question regarding the relationship between the type of knowledge used to solve the task and the perceived relevance the Pearson correlations were calculated for the relevance of the technical content and the type of knowledge for the following tasks: the tasks that were situated at school

Table 6: The results of the questionnaires for the different types.

Type	Task(s)	Relevance technical content (arithmetic mean)	Relevance type for profession (arithmetic mean)
University curriculum and school context	Claisen[a]	2.39	3.22
School curriculum and school context	Glossary[a], School book[b]	3.52	3.56
School curriculum, school context, personalized	Marie[b], Marvin + Leon[a], Laura + Paul[a], Peter + Janina[a]	3.66	3.54
School curriculum, university context, personalized	Luisa + Max[b]	2.86	3.36
School curriculum, context not clear, personalized	Hannah[a]	3.77	3.48
University curriculum, university context, personalized	Max + Tim[a], Daniel[a], Johanna + Tim[b]	2.91	3.29

[a] 2017–18.
[b] 2018–19 (strongly disagree (1) till strongly agree (4))

(school curriculum, school context) and the tasks that were situated at university (university curriculum or university context). For the tasks that were situated at school, the following results were obtained: the relevance of the technical content and the school knowledge correlate positively (0.197; the correlation is significant at the level of 0.01 (2-sided)) while the correlation with the university knowledge is negative −0.055 (significance: 0.423). The task is therefore perceived more relevant when using the school knowledge and less relevant when using the university knowledge. For the tasks that were situated at university however, the correlations are very similar: for the school knowledge: 0.282 (significance: 0.001) and for the university knowledge: −0.067 (significance: 0.423). The students seem to assess the use of their school knowledge as more important than the use of the university knowledge. Because the students are at the beginning of their university studies the school knowledge should be more present and established. Beyond that, the fact that a big part of the school content is also part of the university curriculum can be a reason for the relatively small correlations; for the students it is not easy to distinguish between those two types of knowledge.

Research question 4: How do students rate the tasks with regard to competences in the field of communication?

The tasks, especially the tasks with school context, call for communication. General communication skills should be encouraged by solving the tasks. The ability to use the technical language and to explain facts should also be promoted. Table 7 shows the results from the questionnaires.

The students rated the items for the new tasks between agree and strongly agree (3.29 – 3.62). All skills are therefore promoted. The items for the traditional tasks were rated lower (2.89 – 3.34). The biggest difference is recognizable for the item "the task promotes my ability to communicate". Statements of the students during the focus group interviews regarding the initiation of competences on the field of communication by the new tasks are: *"because in fact especially because, with all tasks (comment: meant are the new tasks), it is often the case that we discuss what the solution should actually look like"* and *"especially when the task itself was trickier, because this sometimes led to misunderstandings among each other. With the partner one could discuss what could be meant then and how one would tackle or would like to solve this problem and how the partner sees this"*. The initiation of competences on the field of communication is therefore realized when the students must discuss possible solutions to their task at hand. However, traditional tasks are also suitable for the promotion of technical language and the ability to explain facts. The Pearson correlation was calculated to check the

Table 7: The results of the questionnaires for the communication skills (for the tasks with school context and school curriculum).

Item	The task promotes my technical language	The task promotes my ability to communicate	The task promotes my ability to explain facts
Arithmetic mean and standard deviation (traditional task)	3.26 (0.694)	2.89 (0.807)	3.34 (0.712)
Arithmetic mean and standard deviation (new task)	3.29 (0.717)	3.62 (0.695)	3.51 (0.626)

(strongly disagree (1) till strongly agree (4))

relationship between those three items. All correlations are significant at the level of 0.01 (2-sided). Table 8 shows all correlations.

The correlations are between 0.314 and 0.429 and are therefore medium. The items “ability to explain facts” and “ability to communicate” correlate with 0.429 strongest. Cronbach’s α for those three items is with 0.622 satisfactorily.

Research question 5: What elements should tasks following the SRCK-concept contain to be suitable for using in written exams and therefore also suitable for testing the learning outcome?

In both written exams one task designed following the SRCK-concept should be solved by the students. Tasks with a lot of text, as are often used in mathematics, are not very popular with students at school as described for example by Prediger (2010). To solve such tasks many competences must be used, not only mathematical understanding. Tasks with a lot of text are for our students, as we observed in many seminars, also not very popular. In written exams those tasks were often not solved at all. We assume that the amount of text was deterrent. The tasks which are designed following the SRCK-concept however, are in comparison with a traditional task equally good (Cohen’s $d = 0.016$) or better solvable (Cohen’s $d = 1.602$) by our students as shown in table 9. For the comparison, the traditional tasks were rated by two experts in order to identify tasks that were equally complex and difficult as the task after the SRCK-concept.

It seems that the positive associations that the students have with this type of tasks can contribute to good results in an exam situation. Therefore, the amount of text appears to be not decisive, but whether the text is appealing. When comparing the tasks, the following features are contained in both: university context, personalized and content from the lecture and seminar. Different is only the context story: in the task in the first written exam, the student Julia must provide a synthetic plan with chemicals for her practical studies in organic chemistry. In the task in the second written exam, the students Jan and Timo must formulate a Wiki on nucleophilic substitution as an additional task for their chemistry study. The first task is very realistic because all students have been or will be in this situation. The second task is a bit more exotic and seems therefore not to

Table 8: The Pearson correlations for the items “communication skills” ($N = 214$).

	The task promotes my technical language	The task promotes my ability to communicate	The task promotes my ability to explain facts
The task promotes my technical language	$r = 1$	$r = 0.314^{**}$	$r = 0.331^{**}$
The task promotes my ability to communicate	$r = 0.314^{**}$	$r = 1$	$r = 0.429^{**}$
The task promotes my ability to explain facts	$r = 0.331^{**}$	$r = 0.429^{**}$	$r = 1$

**The correlation is significant at the level of 0.01 (2-sided).

Table 9: The results of the written exams.

Written exam	Traditional task: percentage of points achieved (arithmetic mean and standard deviation in % of the achievable points)	Task following the SRCK-concept: percentage of points achieved (arithmetic mean and standard deviation in % of the achievable points)	Cohen's *d*
First date (*N* = 29)	20.00 (18.33)	55.35 (25.25)	1.602
Second date (*N* = 21)	45.50 (31.34)	45.94 (23.87)	0.016

be as realistic as the first task. This could also be one reason why the students were more successful in solving this task. However, first indications for a positive learning outcome resulting from the application of the newly designed tasks are given.

Limitations

The analysis of the new tasks discussed in this paper was conducted with two groups of chemistry teacher students with $N = 18$ till 42. The numbers depend on the presence of the students in the respective seminar. However, for our student body the figures are representative because almost all students participated in the seminars. It was therefore not possible to enlarge the number of participants although for the comparability of the results this would have been favorable. Because the results are conclusive they should be of interest for other teachers in the field of organic chemistry. By conducting a mixed-methods study and therefore including qualitative data to better understand the quantitative data, a thorough analysis was possible. Although the contexts and contents of the tasks were designed for our students, it is easy to transfer the results to the design of own tasks.

Conclusion and outlook

The newly designed tasks following the SRCK-concept are suitable for use in university seminars and written exams as well. The tasks are perceived as more relevant by preservice chemistry teachers in comparison to traditional tasks. The most important features for the design of the tasks are if the content belongs to the school curriculum, the situation described in the task is realistic and the tasks are personalized. For future use in the seminars this should be considered when designing new tasks. The new tasks were also perceived as suitable for the development of skills in communication and in explaining of facts. The tasks used in the written exams were solved equally good or better. However, if the content of the task does not belong to the school curricula, a context at university or at special classes at school or STEM-competitions should be selected. The results of the focus group interviews showed that the content at school differs according to school or federal state. For the perceived relevance of the tasks it is therefore important that the context in the task still is realistic. Such new tasks will be designed for master students because the content of their lecture includes topics that are most likely no part of the school curriculum. The evaluation of the use of these new tasks will also focus on the investigation whether the students use their university knowledge while solving these new tasks. To accomplish this, the evaluation will include the questionnaire and open questions as well. The results of this evaluation will be published in due course.

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