Research article

Jolanda Hermanns*

How do pre-service chemistry teachers rate the importance of content in organic chemistry during their chemistry studies at university?

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Abstract: In this article a cross-sectional study on the students' rating with regard to the contents in organic chemistry will be discussed. Pre-service teachers rated the contents with a questionnaire during their bachelor or master studies. It was shown that the pre-service chemistry teachers during their master studies rated the content as more important than the bachelor students. One possible explanation can be that the master students have teaching experience due to their internships at school whereas the bachelor students can only rely on their experience from their own school days. Overall, content belonging to the school curriculum in the federal state "Brandenburg" where the pre-service teachers' university is located was rated better than content that was not a part of this curriculum. Concepts were not rated significantly better than the content. Because of the importance of conceptual knowledge for the future profession as a teacher, the courses in organic chemistry will be redesigned with a clear focus on concepts.

Keywords: content knowledge; organic chemistry; pre-service chemistry teachers.

Introduction

"The more you know about science, the more you will be able to provide a framework to help children think in scientific ways; in so doing you will also represent the subject with integrity" (Carre, 1998, p. 103). Many studies describe that content knowledge (CK) is necessary for gaining pedagogical content knowledge (PCK) as for example the studies from Van Driel, de Jong, and Verloop (2002); Markic, Valanides, and Eilks (2006); Kply, Heikkinen, and Assunta (2009). Together with pedagogical knowledge (PK), CK and PCK belong to the professional knowledge of teachers, as described by Shulman (1986). It was shown (Hermanns, 2020) that pre-service chemistry teachers rated tasks as relevant if they knew the content from their own lessons at school. As a consequence, the students' rating of the content of chemistry teaching can be a hindrance for their own learning of content knowledge at university if they rate this content as less or not relevant for their future profession. This is problematic as teaching requires transformation of knowledge. Mayhunga (2014) defined this transformation as topic specific PCK (TSPCK). Content knowledge therefore is a necessary prerequisite for the development of PCK (Friedrichsen et al., 2009). The content knowledge teachers need have to be learned at university; during their internship at school ("*Referendariat*") they do not develop additional CK substantially (Kleickmann et al., 2013). When we accept that the preservice chemistry teachers' most important learning opportunity for gaining CK is their time at university (see Kleickmann et al., 2013), then it is important to know if their rating of curricular matters is different during bachelor or master studies. It was shown (Hermanns, 2020) that students in their

***Corresponding author: Jolanda Hermanns**, Center for Teacher Training and Education and Department of Chemistry, University of Potsdam, Potsdam, Germany, E-mail: jolanda.hermanns@uni-potsdam.de. <https://orcid.org/0000-0001-7422-6350>

second year rated tasks as relevant if they knew the content from their own lessons at school. To investigate whether pre-service chemistry teachers during their bachelor or master studies rate the importance of content and concepts for their future profession differently, a study with pre-service teachers was conducted.

Research goals

Pre-service teachers use their experience from their own school days to rate the contents of their university courses (Hermanns, 2020). This was the starting point of this study. The contents of the university study for future chemistry teachers in Germany is defined by the KMK (Kultusministerkonferenz, 2019), an alliance of all ministers responsible for school education in Germany. This should ensure that, regardless of the university, the contents of the teacher education is nearly the same in the whole country. There are however great differences between the school curricula in chemistry (Hermanns & Keller, 2019). If students who went to school in one federal state are willing to learn only the contents that are important in that state, they would miss contents that are important in other federal states. To ensure that the future teachers can work in each federal state, it is important that all contents needed are part of the university study.

During their time at university the students have several internships at school where they also can teach independently. It seems therefore possible that master students, compared to bachelor students, rate the content in organic chemistry differently.

This led to the following research question:

How do pre-service teachers rate the contents and concepts in organic chemistry with regard to the school curriculum in the federal state where the university is located during their bachelor or master courses on organic chemistry?

Design

The study was developed, conducted and evaluated as a cross-sectional study in winter 2019–20 at a German university in the federal state (“*Bundesland*”) of Brandenburg. The majority of the students went to school in Brandenburg or Berlin - both federal states have the same curriculum. The students of the course “Organic Chemistry I” (bachelor) and the students of the course “Organic Chemistry II” (master) were part of this study. At our university 8 % of the students are pre-service teachers for lower secondary schools (“*Sekundarstufe I*”) only and 92 % of the students are pre-service teachers for both lower and higher secondary schools (“*Sekundarstufe I + II*”). The bachelor students enroll in the course “Organic Chemistry I” in their third semester (second year); 34 students participated. Five students repeated the course and were therefore in the fifth semester (third year). The master course is situated in the seventh semester (fourth year). The master students ($N = 19$) already had experience with teaching (during their bachelor study they take part in three school internships); the bachelor students had no experience with teaching in their first year. Both groups received the same questionnaire in their first lecture. All contents are part of our university curriculum and of at least one school curriculum of the other federal states. All parts of the study will be discussed below.

The questionnaire used in this study

For the rating of the students a questionnaire was developed. It consists of three parts: a rating whether contents are very important for future teachers, the rating whether concepts are very important for future teachers and an open question: which content and concepts are missing? For the evaluation of the first two parts a four-item Likert scale was used (Likert, 1932). 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”) (Allen & Seaman, 2007). Table 1 shows the contents and the concepts of the questionnaire.

Table 1: Contents and concepts of the questionnaire.

Contents	Concepts
Aldehydes, alkanes, carboxylic acids, alkenes, alkynes, alcohols, amino acids, aromatic compounds, chelates, enzymes, ester, ether, dyes, fats, halogen alkanes, ketones, carbohydrates, synthetic materials, pharmaceuticals, pH indicators, proteins, soaps, surfactants, detergents, silicones, siloxanes, vitamins.	Particle concept of matter, structure-property relationships, reaction mechanisms in organic chemistry.

The ratings were evaluated by using the program SPSS and the results of the open question were clustered and summarized according to Kuckartz (2016). The excerpts used for this paper were translated from German to English.

Results and discussion

Research question: how do pre-service teachers rate the contents and concepts in organic chemistry with regard to the school curriculum in the federal state of Brandenburg during their bachelor or master courses on organic chemistry?

To answer this research question, an overview of the contents at school was analysed by using the summary in the publication of Hermanns and Keller (2019). A Mann-Whitney-Test was conducted and effect sizes were calculated for the statistically significant results ($p = 0.010$ – 0.051). The arithmetic mean and standard deviation for the students' ratings as well as the effect size r (Pearson's correlation) are given in Table 2. The contents that are not part of the curriculum in Brandenburg are in bold.

The following discussion will first focus on the statistically relevant results. The second part will also discuss those results that are not statistically relevant, because these results can be of interest for practitioners who teach organic chemistry or who are involved in teacher education.

Statistically relevant are the results of the rating of the topics aldehydes, carboxylic acids and alkenes and of the particle concept of matter and the concept of structure-property relationships. The master students' ratings of the contents are better than the bachelor students' rating ($p = 0.010$, 0.02 and 0.240 ; $r = 0.215$, 0.178 and 0.131). In addition, especially those concepts that are important at school are rated better by the master students: the concepts "particle concept of matter" and "structure-property relationships" are rated with 3.47 (bachelor) and 3.79 (master) and therefore between "agree" and "strongly agree". The master students rate these concepts significantly better ($p = 0.045$ and 0.033 ; $r = 0.138$ and 0.156). If we take into account that the students rate content that they know from their own school days as more relevant (Hermanns, 2020), the better rating by the master students can be explained on the one hand by their internships at school. They don't have to rely solely on what they remember from their own school days, but they also have new experience which content is important at school as a result of their own teaching during their internships. However, the assumption that the internships influence the master students' rating is supported by their rating of the concepts.

Most results from the questionnaires are not statistically relevant. However, those results will also be discussed, beginning with the contents that are not part of the curriculum in our federal state. For those contents, the arithmetic mean is 2.72 for the rating by the bachelor students and 2.91 for the master students. The difference in the rating is relatively small. It can be possible that the master students recognize the importance of content that is not part of the school curriculum, because they consider such content as an additional learning opportunity or it is their opinion that teachers also have to know content that is not a part of the curriculum. The contents chelates (2.09) and ketones (2.82) were also rated as being less important for their

Table 2: Contents at school and the ratings of the students.

Contents/concepts	Rating bachelor students (<i>N</i> = 34) Arithmetic mean and (standard deviation)	Rating master students (<i>N</i> = 19) Arithmetic mean and (standard deviation)	<i>r</i>
Aldehydes	3.28 (0.729)	3.79 (0.419)	0.215
Alkanes	3.82 (0.459)	4.00 (0.000)	
Carboxylic acids	3.30 (0.810)	3.79 (0.419)	0.178
Alkenes	3.79 (0.485)	4.00 (0.000)	
Alkynes	3.74 (0.511)	3.89 (0.315)	0.131
Alcohols	3.82 (0.521)	4.00 (0.000)	
Amino acids	3.16 (0.767)	3.32 (0.671)	
Aromatic compounds	2.94 (0.933)	3.37 (0.761)	
Chelates	2.09 (0.765)	2.16 (0.765)	
Enzymes	3.03 (0.834)	2.84 (0.834)	
Ester	3.59 (0.609)	3.68 (0.478)	
Ether	2.85 (0.821)	3.21 (0.918)	
Dyes	3.09 (1.042)	3.42 (0.692)	
Fats	3.35 (0.774)	3.42 (0.692)	
Halogen alkanes	2.79 (0.857)	3.16 (0.898)	
Ketones	2.82 (0.904)	3.21 (0.787)	
Carbohydrates	3.47 (0.706)	3.68 (0.478)	
Synthetic materials	3.18 (0.797)	3.32 (0.749)	
Pharmaceuticals	2.42 (0.936)	2.68 (0.582)	
pH indicators	3.62 (0.660)	3.32 (0.749)	
Proteins	3.29 (0.760)	3.47 (0.612)	
Soaps, surfactants, detergents	3.12 (0.977)	3.58 (0.607)	
Silicones, siloxanes	2.42 (0.902)	2.32 (0.749)	
Vitamins	2.62 (1.129)	2.79 (0.713)	
Particle concept of matter	3.45 (0.617)	3.79 (0.419)	0.138
Structure-property relationships	3.48 (0.508)	3.79 (0.419)	0.156
Reaction mechanisms in organic chemistry	2.76 (0.890)	3.16 (0.765)	

chemistry studies, although the rating of the content ketones with an arithmetic mean of 2.82 is near “agree”. Although those two topics are at some point part of the school curriculum, it is possible that the students did not have them at their school. Differences between schools of the same federal state can be observed (Hermanns et al., 2019).

As all contents in the questionnaire are part of at least one school curriculum, the students should rate all contents as important for their future profession. They seem to focus on becoming a teacher in the federal state where they first went to school and now go to university.

However, the other content (that are part of our school curriculum) is rated better by both groups. The arithmetic means for the other content are 3.33 (“agree”) for the bachelor students and 3.53 (“strongly agree”) for the master students. Noticeable in this context is the master students’ rating of the topics alkanes and alcohols, which are part of the school curriculum for pupils between 15 and 16 years. Those topics are rated with 4.00 (very important). If they taught those topics during their internships this would explain this very good rating. On the other hand, it can be possible that the master students rate content better because they know the significance of content for gaining PCK (the master students also had already more courses on PCK than the bachelor students) or have the opinion that a teacher has to know more, as stated before. The concept “reaction mechanisms in organic chemistry” is rated with 2.76 (bachelor) and 3.16 (master) less well than the other concepts. The rating by the bachelor students lies between “not agree” and “agree” and cannot be seen as sufficient. In our opinion, this concept is crucial for learning organic chemistry and should therefore,

regardless of the importance at school, be rated better by the students. This concept is unfortunately used relatively seldom at school, which would explain this rating. However, the master students rate this concept better than the bachelor students (arithmetic mean = 3.16 vs. 2.76), but also not that well. One reason for this could be how reaction mechanisms are taught in a traditional curriculum: the mechanisms are mostly presented as a whole. The initiation of conceptual knowledge to construct reaction mechanisms is seldom a goal of the lecture. The new lecture “Organic Chemistry I”, which will start in winter 2020, will focus on the initiation of conceptual knowledge. It will be very interesting whether the students then rate these concepts differently.

At the end of the questionnaire the open item “The following contents/concepts are missing in my opinion” was answered by the students. The bachelor students did not voice their opinions at all. One reason can be that they are at the beginning of their study and do not yet have an overview which contents and concepts could be important for their teaching at school. This would support the assumption that the internships at school have an influence on the students’ rating. A summary of the opinions by the master students is presented in Table 3:

Unfortunately only four master students used the opportunity to give opinions for contents and concepts. However, the opinion from the student who wanted a more in-depth treatment of the concepts “particle concept of matter” and “structure-property relationships” is interesting, because the master students rated these concepts overall as very important.

Limitations

There are some limitations to this study. First, the study was cross-sectional. It is therefore not clear whether the bachelor students who took part in this study will answer the questionnaire differently when they will be in their master study. However, the results, although most are not statistically relevant, indicate that the rating of the content is different depending on the bachelor or master study. Second, the number of students was relatively small. However, for our university the observed number is quite normal. The results are therefore of interest for the further development of our teaching sessions and encourage us to redevelop our lectures. The results should therefore also be of interest for other researchers and teachers in this field.

Summary and outlook

The study shows that both groups rate content that is part of the school curriculum in Brandenburg better than content that does not belong to this curriculum. Overall, the master students seem to rate the content better than the bachelor students. Two assumptions for explaining this observation have been made: the master students have teaching experience due to their internships at school and rate therefore the content that clearly belongs to the curriculum better or they have a different opinion with regard to the content and they rate the content better, because they see the necessity that teachers have to know more than their pupils (maybe also

Table 3: The opinions of the master students ($N = 4$).

Contents	Concepts
Stereochemistry	In-depth treatment of the concepts particle
Terpenes	concept of matter and structure-property relationships
S_N1 - and S_N2 -reactions	
Polymers	
In-depth treatment of the topics aldehydes, alkanes, carboxylic acids, alkenes, alkynes, ester, ether, carbohydrates and pH-indicators	

because of their teaching experience) or that content knowledge is needed for building up pedagogical knowledge.

However, the results show that some changes in the courses of organic chemistry for preservice chemistry teachers should be made to prevent that the students' focus is only on content. This should also ensure that the students at our university have all the competences needed for teaching in other federal states. By focussing more on concepts than on content this should be achievable. As discussed before, both lectures ("Organic Chemistry I and II") and accompanying seminars will be developed anew with a clear focus on conceptual knowledge in organic chemistry and not on the topics. This shift from topic centered teaching to concept-centered teaching of core ideas is currently also under discussion in the chemical education community (Cooper, Posey, & Underwood, 2017; Cooper, Stowe, Crandell, & Klymkowsky, 2019; Lipton, 2010; Stowe, Herrington, McKay, & Cooper, 2019). The new lectures and seminars will then be evaluated as mixed-methods studies.

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