RESEARCH

Perception of the Relevance of Organic Chemistry in a German Pharmacy Students' Course

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Objective. To investigate German pharmacy students' attitudes toward the relevance of organic chemistry training in Julius Maximilian University (JMU) of Würzburg with regard to subsequent courses in the curricula and in later prospective career options.

Methods. Surveys were conducted in the second-year organic chemistry course (50 participants) as well as during the third-year and fourth-year lecture cycle on medicinal and pharmaceutical chemistry (66 participants) in 2014.

Results. Students' attitudes were surprisingly consistent throughout the progress of the degree course. Students considered organic chemistry very relevant to the pharmacy study program (95% junior and 97% senior students), and of importance for their future pharmacy program (88% junior and 94% senior students). With regard to prospective career options, the perceived relevance was considerably lower and attitudes were less homogenous.

Conclusions. German pharmacy students at JMU Würzburg consider organic chemistry of high relevance for medicinal chemistry and other courses in JMU's pharmacy program.

Keywords: organic chemistry, survey, medicinal chemistry, motivation

INTRODUCTION

High failure rates are a feature of a second-year course in organic chemistry for pharmacy students at Julius Maximilian University's Institute of Pharmacy and Food Chemistry in Würzburg (JMU Würzburg). We conducted a survey to help determine student motivation and to see if this is connected to perceived relevance of organic chemistry to the pharmacy course and the pharmacy career. The contents of the pharmacy curriculum in Germany as well as those of the individual courses are regulated by federal legislation,¹ and therefore the situation at JMU Würzburg's school of pharmacy is representative of other German schools of pharmacy.

A German pharmacy program differs considerably from the typical US program, but has high similarity to European and British pharmaceutical education. The German pharmacy degree is a 4-year program with the first state examination (written) occurring after two years, followed by the second state examination (oral) after the fourth year. So, provided that students do not lose time for preparation for the state examinations or do not have to repeat individual examinations held after each semester, they can finish their university training after four years.

Subsequently, the so-called "practical year" takes place, with at least six months spent in a community pharmacy and another six months spent either in a community or hospital pharmacy, a university research group, or a pharmaceutical laboratory. The third state examination (oral) qualifies for "Approbation," which enables graduates to lead an independent pharmacy.¹

Students start university studies, including pharmacy, medicine, and law (all of which are evaluated in the form of state examinations), after the German high school examination ("*Abitur*") and elementary school, with an overall duration of 12 years. Alternatively, 10 years of school plus a related professional training qualifies for university admission. For pharmacy in particular (and other subjects like medicine), good to very good results on the *Abitur* are necessary for admission. As a result of differences in the federal educational school systems of the German states ("*Länder*") and of the varied duration and quality of chemistry classes in high school, student knowledge in chemistry and organic chemistry can differ considerably.

The two years before the first state examination consist of fundamental courses in physics, general and inorganic chemistry, botany, qualitative and quantitative pharmaceutical analysis, and organic chemistry (in the second year), among others. In the two years following

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the first state examination, pharmaceutical subjects including pharmacology, clinical pharmacy, and pharmaceutical/medicinal chemistry are lectured and examined on.¹

The organic chemistry course at JMU Würzburg (and in similar fashion at other German universities offering pharmacy programs) consists of a 6-week practical course (168 hours spent in the laboratory) dealing with synthesis and purification of organic and drug molecules (eight compounds [eg lidocaine]), four hours of lectures/week, a mid-course oral examination given by teaching assistants supervising the practical course (usually postgraduate students), a tutorial by senior chemistry students, in which questions are answered and tests for the final assessment at the end of the course are practiced, and the final assessment as written examination with essay-like, concise questions. Regarding assessment procedures, the final assessment in all junior chemistry courses including the organic chemistry course consists of written examinations with specific and concise questions, which can be answered with one sentence or a structural formula, to a lesser degree essay-like questions, and a passing mark (grade) of 50%.

The problem we wanted to investigate was the high failure rate (>50%) for the final assessment. A repeat examination is offered several weeks after, and the remaining two repeat attempts can only be taken after the following semester. The failure rate in organic chemistry and basic chemistry, which is taught in the first year, increased over the past years and then leveled out over the past two years. The organic chemistry course is identical for both pharmacy students and a smaller cohort of food chemistry students (usually around 15%).

To identify the reasons for the high failure rates and to improve student performance without lowering the academic level of the organic chemistry course, we performed a survey among students participating in the course. We also surveyed students in the two years following the first state examination. We approached the issue with two hypotheses: (1) Previous high school training in chemistry—organic chemistry in particular—does not provide sufficient background knowledge to follow and benefit from this part of the course. Students have insufficient time to prepare adequately for the assessment because they have to gain the basic knowledge first; (2) Students believe organic chemistry is not relevant enough to subsequent courses and/or to their anticipated career, and this belief has a demotivating effect on their learning.

METHODS

Two surveys were conducted in the summer semester of 2014 at JMU Würzburg. One survey studied students at the beginning of the second year (ie, within the organic

chemistry course for 50 second-year students (“junior students,” 42 of them pharmacy and eight food chemistry students; 82% response rate). The second survey was conducted among students in the medicinal chemistry lecture cycle (“senior students,” 66 pharmacy students, 39% response rate). The latter group had successfully passed the organic chemistry course and the subsequent first state examination. The response rate of senior students was considerably lower because lecture attendance is nonmandatory at German universities, though still representative.

Students were informed that the survey was anonymous and results would be used for scientific purposes only. Survey administration, ethical considerations, and question design were developed in collaboration with the Center of Innovative Teaching and Learning of JMU Würzburg. The survey was validated by two first-year students by attempting to answer the survey and thereby identifying imprecise questions. Their comments were considered for the final version. Students were previously informed that the purpose of the survey was to help improve student experience in organic chemistry.

The survey instrument consisted of eight question items (Table 1): (1) personal information (gender, current semester, previous professional training); (2) high school and professional training (eg, years of chemistry received in high school, estimate of percentage organic chemistry in the high school chemistry course, how satisfied students were with the level and content of the chemistry course while at high school and subsequently (Table 2). Extra space was provided to include comments with regard to the high school’s training in order to identify putative explanations for students’ attitudes; (3) current academic success (eg, number of repetitions necessary for chemistry and organic chemistry assessments); (4) preferred and attended teaching forms (lecture, practical course, tutorial, peer learning group—in the German system only the practical course is mandatory); (5) expectations regarding the content of future courses and future jobs, especially with regard to the relevance of organic chemistry; knowledge about expected profile of future jobs, etc. (Table 3 and 4); (6) desired job when not taking into account current academic success (to be answered by pharmacy students only); (7) desired job taking into account personal academic success (Table 5, to be answered by pharmacy students only) and (8) relevance of organic chemistry for future courses in medicinal chemistry and for future university courses in pharmacy in general (to be answered by pharmacy students only).

Questions were answered by marking a checkbox at the given number of years or by assigning a score. Students were asked to estimate with a forced choice, 6-item Likert scale (1 = not satisfied to 6 = completely satisfied).

Table 1. Categories of Survey Questions Regarding Relevance of Organic Chemistry to Pharmacy Studies and Practice

Personal Statements
What is your gender?
In which year of the pharmacy/study program are you?
How did you obtain the higher education entrance qualification?
Have you completed training in advance of the study program?
Chemistry in High School
Years of chemistry in school?
What percentage of “organic chemistry” was taught?
Were you satisfied with the course level taught while at school?
Are you satisfied with the level taught retrospectively?
How good was your school performance in chemistry?
Was chemistry a subject of your final examination in high school?
Relevance of Chemistry
Is sound chemistry knowledge relevant for study success?
Is sound chemistry knowledge relevant for professional success?
Is sound organic chemistry knowledge relevant for study success?
Is sound organic chemistry knowledge relevant for professional success?
How relevant do you consider organic chemistry in pharmaceutical/medicinal chemistry?
How relevant do you consider organic chemistry for your future studies?
Career Options
Which professional activities would you like to pursue after your studies?

Table 2. Selection of Collected Data Concerning High School Background of Junior and Senior Students

	Junior Students (%)	Senior Students (%)
Years of chemistry in high school		
2	(8.5)	(12.3)
4	(27.7)	(20.0)
5	(31.9)	(29.2)
6	(21.3)	(12.3)
1,3,7,8	(10.7)	(26.1)
% of organic chemistry taught		
0-20	(56.3)	(43.9)
20-50	(27.1)	(42.4)
50-80	(14.6)	(4.5)
No answer	(2.1)	(9.1)
Satisfaction with level taught prospective ^a		
1	0.0	3.2
2	12.5	12.7
3	14.6	17.5
4	35.4	30.2
5	25.0	17.5
6	12.5	19.0
Satisfaction with level taught retrospective ^a		
1	10.4	6.3
2	10.4	19.0
3	29.2	17.5
4	29.2	33.3
5	8.3	11.1
6	12.5	12.7

^a1=not satisfied; 6=very satisfied

Therefore, they needed to choose either in the direction of “rather good” or “rather poor” and could not choose a neutral position. Taking into account the large set of data gathered by this survey, several aspects can be investigated. Only results with regard to perception of the relevance of organic chemistry (items 5 and 8), teaching forms used by the students (item 4), and basic findings concerning the relevance of prior high school courses (item 2) are discussed in this article.

RESULTS

One hundred sixteen students (84 female, 31 male, and one who did not reveal gender) participated in the study. The majority of junior and senior students had not participated in prior professional training related to pharmaceutical fields (86% and 84.4%, respectively). As shown in Table 2, high school background of both junior and senior student groups are comparable in the years they were taught chemistry in high school. One third of both

groups had received five years of chemistry training. Another third of junior and 20% of senior students had had four years of training. Students were asked to estimate the percentage of organic chemistry taught. This varied to a greater extent when compared to the years of chemistry being taught because in Germany’s federal system, every state can decide on the syllabus independently. Sixty percent of junior students stated that organic chemistry was taught up to 20%. One third of junior students declared this amount was between 20% and 50%. The majority (42.4%) of senior students stated the amount of organic chemistry was in the range 20-50%. Comparing the junior students’ satisfaction with the level taught after finishing high school, the opinion changed to “rather not satisfied” when they had to evaluate this retrospectively. One third was rather not satisfied and another third rather satisfied in the retrospective evaluation. In the senior student group, the amount of students who reported being very satisfied

Table 3. Assessment of Benefit of Organic Chemistry Knowledge in Medicinal Chemistry and the Whole Pharmacy Program Extending Among Junior and Senior Students

	Junior Students (%)	Senior Students (%)
How relevant do you consider organic chemistry in pharmaceutical/medicinal chemistry? ^a		
1	2.4	0
2	0	1.5
3	2.4	1.5
4	19.5	13.6
5	29.3	47.0
6	46.3	36.4
How relevant do you consider organic chemistry for your further study? ^a		
1	2.3	0
2	0	1.5
3	9.3	4.5
4	20.9	25.8
5	30.2	37.9
6	37.2	30.3

^a1=completely irrelevant; 6=highly relevant

(19%) in the prospective evaluation lowered to 12.7% in the retrospective evaluation. One third of these students were rather satisfied in both cases. The amount of students not satisfied (19%) increased in the retrospective assessment of the senior students.

All students participated in the mandatory practical course. Three quarters of the junior students attended the lecture on a very regular basis, which is the same for later stage students. Also the nonmandatory tutorial was attended by both junior and senior students, with 70-80% “regularly” or “very regularly” attending (slightly higher percentage for the senior students). A homogenous distribution of attendance of peer learning groups was reported with similar percentages around every intensity level from “never attending” to “very regularly attending.” Only one third of junior students (31%) in the surveyed organic chemistry course were still within the official and desired time frame (ie second-year students), whereas two thirds (68%) of the senior students were in this time frame.

Asked specifically how useful organic chemistry was for pharmaceutical/medicinal chemistry in the third and fourth years of the pharmacy program, one student (2.4%) considered it “completely irrelevant” and one “moderately relevant” (Table 3). All other students considered it “moderately relevant” (20%), “relevant” (29%), or “highly relevant” (46%). With regard to the further courses in general,

Table 4. Assessment of Organic Chemistry Knowledge for Study and Professional Success Among Junior and Senior Students

	Junior Students (%)	Senior Students (%)
Sound chemistry knowledge is relevant for study success. ^a		
1	2.0	0.0
2	2.0	0.0
3	2.0	4.5
4	4.1	1.5
5	28.6	43.9
6	61.2	50
Sound chemistry knowledge is relevant for professional success. ^a		
1	10.6	3.1
2	8.5	13.8
3	21.3	26.2
4	27.7	29.2
5	25.5	18.5
6	6.4	9.2
Sound organic chemistry knowledge is relevant for study success. ^a		
1	0.0	0.0
2	2.0	1.5
3	4.0	7.6
4	12.0	12.1
5	28.0	34.8
6	54.0	43.9
Sound organic chemistry knowledge is relevant for professional success. ^a		
1	8.3	4.6
2	12.5	15.4
3	16.7	23.1
4	27.1	26.2
5	27.1	23.1
6	8.3	7.7

^a1=total disagreement; 6=total agreement

results were similar, with “moderately relevant” (21%), “relevant” (30%), or “highly relevant” (37%). As with most of the questions, senior students shared the same attitude: “moderately relevant” (14%), “relevant” (47%), or “highly relevant” (36%) for medicinal chemistry and “moderately relevant” (26%), “relevant” (38%), or “highly relevant” (30%) for further courses in general.

With regard to the relevance of chemistry for success in a prospective future job, the results were similar in the two groups (Table 4). Junior students agreed (88%) and senior students almost fully agreed (94%) that sound

Table 5. Probability of Pursuing One of the Given Professional Activities After Studying

Professional Activity	Junior Students		Senior Students	
	Yes (%)	No (%)	Yes (%)	No (%)
Community and hospital pharmacist	91.9	8.10	83.1	16.9
Employee of a pharmaceutical company	56.0	44.0	58.8	41.2
Employee of a health insurance	44.4	55.6	26.7	73.3
Employee of an authority	38.7	61.3	31.7	68.3
Graduate student	29.6	70.4	46.3	53.7

knowledge in chemistry was decisive for future success in studying pharmacy or food chemistry. Being asked whether well-grounded knowledge in chemistry is indispensable for success in their future jobs, distribution was fairly equal between “predominantly agree” to “totally agree,” while 19% of the junior students and 17% of the senior students “disagreed” or “totally disagreed.” The same two questions with regard to organic chemistry gave almost the same results with 21% “disagreement” or “total disagreement” for junior students and 20% for senior students. In general students rate the knowledge of organic chemistry higher for their study success (82% junior students and 79% senior students) compared to their professional success (35% and 31%, respectively).

Students were invited to state their expectations of a prospective career role. Of the senior cohort, 64% and 54% of junior students had precise plans for their future career. However, when they were asked if they knew the technical requirements for this job, only 47% of the senior cohort and 40% of junior students stated they knew this “well” or “very well.” Pharmacy students were asked which future jobs they would like to work in, taking into account their current academic performance. As presented in Table 5, the majority of both junior and senior students considered a job as a community and hospital pharmacist (92% junior and 83% senior students). Half of the students were contemplating a career in industry. Most of the junior students did not consider undergoing postgraduate studies (70%), whereas 46% of senior students were considering that.

DISCUSSION

Germany will be faced with a lack of 50 000 professionals in so called “MINT” subjects (math, informatics, natural sciences, and technology) in the next decades.² Drop-outs from JMU Würzburg in these subjects were at around 50%. Thus improvement of university training and supervision is required. This is irrespective of whether the number of pharmacy students is increasing or decreasing in the respective country.³

Pharmacy students are likely to be interested in science and math.⁴ This is in agreement with the International Pharmaceutical Federation, which strongly emphasizes the

need for “. . .solid grounding. . .in the natural. . .sciences. . .”⁵ With continuous global changes in pharmacy program curricula, a trend toward increasing emphasis on clinical pharmacy, and the close relationship to other health care professions, there might be a misperception of the relevance of basic science courses for the profession as a pharmacist. This holds true for different career paths such as in community pharmacy, where the majority of German pharmacy graduates without an additional graduate degree work, as well as for jobs in hospitals and other health care companies.

Solid knowledge about the educational and motivational background of students is indispensable for the academy to draw the right conclusions for improving students’ learning and maximizing support for them. In our survey, students in both cohorts considered organic chemistry highly relevant for future studies, especially with regard to pharmaceutical and medicinal chemistry. These results were strikingly consistent for both junior and senior students. However one third of junior students and almost half of the senior students thought that solid organic knowledge was not relevant for professional success. This is of course related to the expected future career path of students (Table 5). The majority of students expected themselves to work in a community pharmacy. But only up to one third of the cohort stated that they at least roughly knew what their desired job required (data not presented in table form). This shows that students might not be able to judge whether organic chemistry is relevant for their future job because they don’t know what that job will be.

In previous research at US schools of pharmacy, higher grades in organic chemistry courses were a predictor of academic success.⁶ If this is also the case for German pharmacy programs, reducing failure rates may have a sustained effect on the students’ overall academic success. In accordance with this, Chisholm et al found that math and science performance in prepharmacy courses was a factor in predicting students’ first-year academic performance.⁷ Prescott et al found that chemistry and biology courses in particular were important for a professional career in pharmacy.⁸ Based on these studies, one can assume that pharmacy students are aware of the importance

of natural science knowledge and importance in the pharmacy context as evaluated by us also.

We know from previous studies that insufficient motivational background is not likely to be the only explanation for problems with organic chemistry. A qualitative study by Anderson and Bodner discussed specific problems a cohort of otherwise successful students encountered with organic chemistry.⁹ In contrast to Anderson and Bodner, our students faced the same academic problems with general chemistry as they did with organic chemistry. Based on our data, it seems that students viewed the importance of organic chemistry as high. Junior and senior students rated organic chemistry as highly relevant for future studies, especially for their training in medicinal and pharmaceutical chemistry and to a minor extent for their future professional job. When a lack of motivation is expected this would translate into bad performance. Academic selection within the course and the first state examination would take place and reveal the students with higher motivation and better academic performance in the senior semesters. Yet, this is not the case.

Other studies showed high school work that is done in a motivated and interested manner is accompanied by engagement, participation, and self-regulated learning.^{10,11} The relevance of chemistry was rated high in our survey, which should result in high motivation for this subject. Thus, a lack of self-regulated learning and the willingness to do so should not be the major reason for high failure rates. Instead, reasons must be related to other factors like lack of knowledge from high school, or bad teaching at university level, even though surveys on the quality of teaching in previous years gave no indication of that. Reid discussed the overload of working memory as being a significant obstacle for academic success and proposed changes in teaching approaches.¹² Natural science knowledge is strongly connected with students' performance in high school, depending on the high school teacher. In this context, Hanna et al conducted a study on how students compare their learning at university to that in high school.¹³ The authors concluded that students were not prepared sufficiently for the demands of higher education. High school students are typically not used to being independent learners or capable of structuring learning material. Similar observations were made by McCarthy and Kuh, who found that students' learning habits were already inadequate for high school classes.¹⁴ They found that high school students took too little time to prepare for classes. This translates into weak academic skills and weak practical competences observed later in college and university environments. Fergus and Kostrzewski evaluated the contextualization of chemistry in the MPharm curriculum.¹⁵ The authors stated that chemistry underpinned

pharmaceutical sciences. Students were required to have solid chemistry background knowledge and then learn at the university to transfer this to real-life examples in the pharmacy context (eg, being responsible for patients' safety by knowing about the mechanisms of action, side effects and contraindications of drugs). This also needs highly motivated teaching staff which is not only teaching the solid chemistry background but also transfer their subject to the pharmacy context.

The existence of a teaching problem could not be completely ruled out in our case and is currently being investigated by the faculty and teaching staff involved in the course, and this applies to the general chemistry course also. Moreover, the extent and perception of appropriateness of high school teaching was also investigated. Students rated the satisfaction of the level taught retrospectively rather poor and the percentage of organic chemistry taught to less than 50% (Table 1).

There are limitations to our study, such as the results being based on only one institute of pharmacy in Germany, and the response rate of the senior students was only moderate. Nevertheless, our study points out—with regard to our initial hypotheses—that a lack of motivation is not the reason for insufficient academic performance. Instead, inadequate high school training might be the more obvious reason for low passing rates in organic chemistry in early study phases because students might not have adapted to the new learning environment. This hypothesis is being investigated in more depth but the respective study design is not easy. High school training already ended and data obtained from students regarding this time period is only retrospective and biased because of their development and reflection.

CONCLUSION

German pharmacy students consider organic chemistry to be highly important for their future studies and to some degree relevant for their later jobs, as, for example, community pharmacists. A lack of motivation does not seem to be the explanation for high failure rates in organic chemistry courses. This is encouraging for the faculty members but it doesn't in itself address the serious ongoing problem of high failure rates in organic chemistry. If significant deficits in high school formation in the basic sciences in Germany can be identified, German pharmacy program providers may need to introduce appropriate educational support to help students reach program goals.

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