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Commentary

Business Chemistry: The successful establishment of an interdisciplinary field

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The article presents the development of Business Chemistry at seven German and one Swiss universities. Besides highlighting the course of study in general and its development, the respective universities present benefits but also specific challenges they had to face when introducing Business Chemistry. Followed by a short introduction of Business Chemistry itself, its development and the status quo, every university presented their individual perspectives on the course of study. Overall, the article should provide our readers with an overview of Business Chemistry and sensitize them for the differences in the study programs, even though the courses of study were developed in accordance with all respective universities.

Introduction

Business Chemistry – a course of study settled in two disciplines. In general, Business Chemistry can be defined as a combined study program of the two disciplines chemistry and business. Competencies in the subjects chemistry and business are developed either in a parallel or in a consecutive study program. Depending on the universities and the accessible resources at the time of implementation, the courses and specialization offers can differ. Therefore, at some universities the focus lies on developing general competencies in the field of business, whereas other universities especially focus on the courses at the interface of the two subjects such as innovation management. The chemical part of Business Chemistry is very similar at the respective universities - building competencies in the research fields inorganic, organic, and physical chemistry as well as providing analytical skills.

The initial demand for this combination came not only from industry, but also from the necessity to increase the attractiveness of chemistry as a course of study. In addition, it is quite common in the German area, in contrast to the Anglo-American region, to combine technical and natural science study programs with a business component, i.e., the study programs industrial/business engineering and business informatics. This is also one reason for the different foci of Business Chemistry at the respective universities as mentioned above. The chemical industry, with its practical view and knowledge about common career paths, has demonstrated that even though many chemists initially start in the lab, they often end up in management positions at the end of their careers. Because of this, the Business Chemistry program aims to educate students in both disciplines. Furthermore, chemical companies benefit greatly from employees having expertise in both fields and understanding the chemical processes of production. Business Chemists have the capability to look from a different perspective on business processes and value creation, which ultimately benefits the company by questioning the status quo and mediating between the business and chemical perspectives. Furthermore, the development of academic education changed in the last years. The demand for interdisciplinarity has increased, which in the end

leads to the introduction of plenty of combined study programs beside Business Chemistry. The idea for Business Chemistry originates from the decreasing interest in studying chemistry in the 1990s. The path of a traditional chemist is relatively inflexible and typically ends with a PhD. With the introduction of Business Chemistry, the universities offered potential students a new career perspective, building competencies in two different research fields. Due to the two-sided education, students are more flexible in choosing their individual career path – by having the chance to end their study with a bachelor or master degree and directly enter the workforce.

In figure 1, an overview is given about the important milestones of the development of Business Chemistry. Starting with the introduction of the first course of study in the 1990s, followed by the restructuring from diploma to the bachelor/master program in 2000s and ending with the reaccreditation of the course in 2010s.

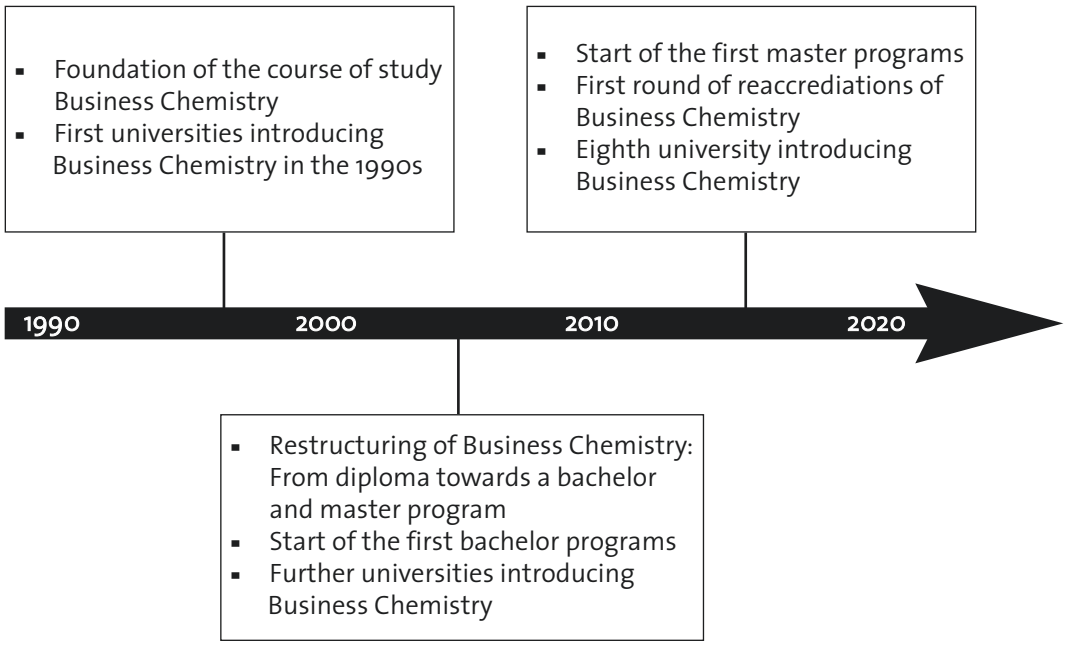
The article does not aim to present an overall picture of Business Chemistry, but it should provide our readers with different perspectives and understandings of Business Chemistry as a course of study at the respective universities. We invited persons from German and Swiss universities, who paved the way for implementing Business Chemistry, to comment on the benefits, challenges and chances of this implementation. The commentaries are presented in chronological order of the implementation – starting with Düsseldorf as one of the first institutes and ending with Regensburg recently introducing Business Chemistry as a course of study.

From Kaiserslautern to Düsseldorf

Prof. Dr. Walter Frank, Chair for Materials and Structural Research, Institute of Inorganic and Structural Research, Heinrich-Heine University in Düsseldorf

One topic of discussion from the Conference of Departments of Chemistry (KDC)[1] in the mid-1990s was the intensive examination of new concepts for specialization in the classical diploma program of chemistry. The result was the development of the Würzburger model (also referred to as 6+4 model), which offered a new specialization type of study by combining six terms of chemistry with

Figure 1 Milestones of the development of Business Chemistry as a acourse of study.



1 Association of Chemistry Departments from German Universities and technical universities, as well as the German Chemical Society (GDCh)

four terms of business economics – from then on called Business Chemistry.

First initiatives for developing programs according to the new concept of business chemistry started at the universities of Kaiserslautern, Düsseldorf, Münster, Clausthal (TU), Kiel and Ulm. Almost all of these places are still part of the list of universities with Business Chemistry programs today.

After intensive negotiations between the departments of chemistry and business engineering, highly complicated by the conditio sine qua non that a study program in business engineering with specialization in chemistry had to start at the same time, the first study program of Business Chemistry started in winter term 1997/98 at the University of Kaiserslautern (today Technical University of Kaiserslautern) according to the 6+4 model, with some higher-term students transferring from the diploma chemistry program. As the author, teaching at that time in Kaiserslautern, remembers well, a young lady from this small group of students received the first diploma in Business Chemistry ever and immediately found her way to a well-known chemical company in Ludwigshafen.

At that time, as a common project from the institute of organic and macromolecular chemistry and the faculty of business sciences, intensive preparations were made to introduce a new study program for business chemistry at the Heinrich Heine University in Düsseldorf, as well. In winter term 1999/2000 the new study program was introduced, welcoming a first group of about 30 first-term students with support of a well-known Düsseldorfer company.

Compared to the Business Chemistry programs of other universities, at the Heinrich Heine University, it has always, from the beginning of program development, been of great interest to achieve the best possible synthesis of the two important subjects, chemistry and business economics, from the first day of study on, and also to achieve a synthesis of the very different subject cultures, as well. This 'parallel combined model', which can be seen as an 'interface' between two disciplines, has gained growing popularity at Heine University since 1999. It was also prototypic for some other universities in further developing their business chemistry programs. Nowadays, the 'parallel combined model' in Düsseldorf combines a seven-term bachelor and a three-term master program, both in 'parallel mode'. The number of graduates is highly convincing and they have achieved a high level of recognition in chemical industry, but also in other commercial sectors. The Business Chemistry program in Düsseldorf has therefore already been a story of great success for 17 years now.

Münster: The next step

Prof. Dr. Jens Leker, Institute of Business Administration at the department chemistry and pharmacy and Chair for Business Chemistry, Westfälische Wilhelms-University in Münster

The idea to establish Business Chemistry as a subject at the University of Münster was born in 1998. The first discussions between the university and Degussa-Hüls AG, as an initiator and potential sponsor, led to the decision for implementation. Following these initial discussions, the "Professorship of business in natural science with focus on chemistry" was established as an endowed chair in 1999. Subsequently, the "Institute for business administration at the department of chemistry and pharmacy" was founded in 2000. The leadership of the institute is characterized by its professorship, which is primarily a member of the department of chemistry and pharmacy, but also, through a cooperation, has a secondary membership to the department of economics. The initial endowment was the basis for the foundation of the institute and therefore for the affiliation to the university's budget. The institute had the responsibility to offer specific lectures for management qualifications in natural science courses as well as to design and supervise the course of study Business Chemistry from scratch.

As already mentioned in the previous commentaries, Business Chemistry can be designed in two ways – a parallel or a consecutive study program. In Münster, we offer a master course of study in business chemistry for students with a bachelor degree in natural science. This allows students, who initially started to study chemistry, a reorientation after their bachelor degree without losing their time and chemical knowledge. The master course Business Chemistry is designed to provide the students with an understanding of fundamental economic concepts as well as in-depth chemistry knowledge. Furthermore, knowledge and capabilities in the field of technology and innovation management are taught. By this approach, the business chemistry students are prepared for their future function as problem-mediator and -solver in research-intensive industries. The master degree in business chemistry is in most cases received following a practice-oriented master thesis about modern economic concepts for problem solving applied in the chemical and pharmaceutical industry. Moreover, the institute offers the possibility to do a PhD in this new interdisciplinary research field. Even though most of the students directly enter the workforce following the completion of their

M.Sc., 36 PhDs have successfully received their degree in the last 15 years, which further serves to promote Business Chemistry in the academic world.

Kiel's Business Chemistry model

Prof. Dr. Ulrich Lüning, Chair for Organic Chemistry, Otto Diels-Institute of Organic Chemistry, Christian-Albrechts-University zu Kiel

At the end 1990s, the Kiel diploma study program was reformed and the main study course was divided into two stages so that after the pre-diploma (four semesters), four half-semester modules had to be completed in the fifth and sixth semester. For the chemists, these modules were practical trainings in Inorganic, Organic and Physical Chemistry as well as an additional subject to be chosen by each student. For the newly designed study program Business Chemistry, nearly the same structure was used, but instead of the chosen subject in the last module, a chemical thesis is completed. In this manner, a six-semester basic chemistry study course corresponding to today's bachelor studies was completed. In the following four semesters, the prospective business chemists studied economic subjects and completed their business chemistry studies with their diploma thesis in the tenth semester.

Only after the pre-diploma did the students need to decide which degree they wanted to obtain, which was the main advantage of this system. Nearly all courses were completed together with the 'thoroughbred'-students of each subject by this successive structure of first studying six semesters of chemistry followed by four semesters of economic sciences. The business chemistry students' training level, professional discussion and language did not differ from those of the single subject students. But unfortunately, there were also disadvantages in these successive studies. When the students completed their studies, their last contact with chemistry was two years ago. Furthermore, the students had either contact to chemistry or to economic sciences . So they learned about both topics and their languages very well but not parallel at the same time.

When the change to the bachelor-/master-system had to take place, out of this struggle an opportunity was realized to alter the studies' structure. Now, the prospective business chemists study either together with chemists or the economists in their disciplines so they learn about their thinking and their language in close contact. But now, both studies happen in parallel, taking place at the same time. Thus, the students learn and practice from the beginning to deal with natural sciences as well as with business.

Where is the combining element? In the bachelor studies, there is a compulsory business internship which needs to last at least ten weeks. During this time, attention is paid to the presence of chemical- as well as business-related aspects. This internship is the reason for the bachelor studies' duration of seven semesters. In the master studies, chemical as well as economic topics are deepened. In the third master semester, in total the tenth semester, the six-month Master thesis is performed which is most usually completed in a chemical company. Hereby, knowledge which was gained in both disciplines is directly used for the studies' completion. Some graduates even get to know their first employer through their work in the economy.

After nearly twenty years of Business Chemistry in Kiel, the Business Chemistry study program has clearly found its place at the Christian-Albrechts-University. There is a high demand for this study program, which makes a Numerus clausus necessary. The graduates are requested in all parts of the chemical industry and in the related economy.

Business Chemistry in the field of tension within differentiating interests - a subject shapes itself

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Kaiserslautern, as the origin of Business Chemistry, went through a similar process compared to Kiel, with all the advantages and disadvantages mentioned above.

The Bologna-Reform offered the chance to enlarge the basis of the diploma Business Chemistry study program. Graduates of the bachelor chemistry study program could have gained further qualifications in the master Business Chemistry study program. Unfortunately, it was not possible to realize the required structures in practice. In 2013, two new study programs received the official seal of the Accreditation Council: a bachelor study program with specialization in economic sciences and a master study program 'Business Chemistry'.

In the bachelor study program, chemical issues and themes are predominant with a curriculum share of about 80%. The standards of the chemical education are orientated at the bachelor chemistry study program. The curriculum of economic

sciences consists of the mandatory modules 'Basics of Business Administration', 'Basics of Accounting', and 'Financial Management'. In addition, there is a choice of four out of the following modules: Production, Marketing, Investments and Financing, Labor Organization, Strategic Management, Operations Research and Business Informatics. The teaching of the economic part covers 20% of the curriculum. By the introduction of newly designed integrated courses in chemistry, space for additional economic sciences courses could be created. The students gain analytical competencies within a lecture series, in which lecturers and professors from Physical Chemistry, Inorganic Chemistry and Organic Chemistry work together. In the further practical advanced education, the lecturers and tutors follow the same process with an Integrated Practical Synthesis training in which especially working techniques are emphasized and taught. The study structure leads to a more intensive combination of chemistry and economic sciences and clearly differentiates itself from the study program 'Business Engineer with specialization in chemistry'.

Graduates of the bachelor study programs ‚Chemistry with specialization in economic sciences' and 'Business Chemistry', if they come from other universities, have the opportunity to finish the four-semester master study program 'Business Chemistry' in order to choose an ambitious and challenging profession later on. The Departments of Chemistry and Economic Sciences share the same amount of course contents in the curriculum of the master study program. The students may choose their focus according to their preferences and their abilities. From the second semester on, the students get the opportunity to receive insights in professional fields at the interface between natural and economic sciences within research projects.

The study program's guiding principle, realizing intellectual added value by parallel confrontation with chemical and economic topics, supports the newly-designed module 'Business Chemistry', to which high-level industry representatives could be attracted. In the module 'Key Performance Indicators', the students learn to reflect and to realize natural science aspects of the active ingredients synthesis within an economic context. Therefore, company foundation, company development, investments and market domination are essential. 'Key Performance Indicators' represents an interactive innovative interface between the different specializations and offers the students an ambitious confrontation with possible professional fields.

A clearly structured study program was developed within the last two decades. By networking within the specialist group, a regular exchange with representatives from all other German and Swiss Business Chemistry locations takes place, ensuring standards which are much appreciated by the economy. In comparison to other universities the environment of the Technical University Kaiserslautern is highly appreciated by students and teachers.

Business Chemistry at University of Zurich: Fit for Chemical Industry Careers

Prof. Dr. Stefan Seeger, Chair of Physical Chemistry, Department of Chemistry, University of Zurich

The chemical and pharmaceutical industry is one of the key factors in the Swiss economy. In the perception of the Swiss population, the combination of chemistry and business is therefore a natural and highly valuable composition of disciplines. Major companies, e.g. Roche and Novartis are global players in the pharmaceutical business, while Clariant, Syngenta and Sika are examples of global market leaders in chemical industries, respectively. Furthermore, there are many large firms in the fine chemical industry and a high number of SMEs (small and medium-sized entreprises). The Swiss chemical and pharmaceutical industry is one of the most important segments in the Swiss economy.

The interdependency between different disciplines has grown enormously and is supposed to grow further and even faster. The industry has always faced tremendous changes and constantly will, e.g. due to the approaching "Industry 4.0" challenge. However, the labor force's background is largely the same as decades ago: Economical background is provided by business faculties of universities to business students, molecular science knowledge is given by faculties usually called "Faculties of Science" to chemistry students and other scientists, and practical knowledge is offered later in companies' advanced training courses. Besides updating the technical content of the programs, this principle is carved in stone in some cases until today. However, a program established in Switzerland exclusively at University of Zurich brings together disciplines for the first time, which is necessary for a successful execution of tasks in modern chemical and pharmaceutical companies.

The students experience the atmosphere in the business faculty together with the business students and in chemistry from the first day with their science colleagues. This concept enables them to communicate with chemists and business people during their studies and later in companies equally well. There are no linguistic or even psychologi-

cal barriers. The bachelor program includes a bachelor thesis where the students work for the first time on a project at the interface of chemistry and business -guided by an experienced supervisor. This may include even an experimental laboratory component; however, this is not mandatory. Market studies, profitability calculations and similar tasks are typical. The Master program at University of Zürich includes 4 modules provided in close collaboration with chemical and pharmaceutical industry and is exclusively application oriented. Subjects are project management, intellectual property, marketing in chemical industry, emerging markets, logistics, and more. Further, the students collect credits by industrial internships and even the Master thesis is often performed in or in collaboration with companies. Using these instruments, the students experience the industrial world at an early stage during their university studies, learn the challenges they have to expect during their career and have the opportunity to build up a network beyond academic institutions.

Finally, the question remains, if this concept far from traditional university-based training withstands a proof in the real world. The answer is an explicit YES. The students enjoy the time at the university, and the industrial responsible persons love it as well: many companies have hired more than one of the graduates and value the program as a smart recipe of business and chemistry. And the chance to find a position in pharmaceutical, chemical and related industries or consulting business is very high: more than 80% of the graduates enter the final exam already with a signed labor contract in their pants pocket.

Application-orientated Business Chemistry – the model of the Fresenius University of Applied Science

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The Fresenius University of Applied Science based in Idstein (Hesse) is the only University of Applied Science (HAW) in the German-speaking area which offers both a bachelor and a master study program for Business Chemistry. The focus of Business Chemistry is on the practical and application orientation. This is emphasized by the University's mission statement: 'Learning and researching with a practical orientation, living internationality, demanding and encouraging students'. With the introduction of the study program reform based on the Bologna Process and the conversion to the bachelor-master system, in 2008 the bachelor program and in 2013 the master program 'Business Chemistry' were developed.

The bachelor program is designed as a six-semester full-time study program (180 ECTS credit points) following a consecutive model. In the first four semesters, the students gain basic knowledge in chemistry, physics and mathematics. In the fifth semester, the students extend their qualification profiles with selected courses of economics and the addition of an application-orientated case study at the interface between chemistry and business administration. Since 2015, we perform this case study within the project Student2start-up in cooperation with the Wissensfabrik Deutschland e.V. (Think Tank Germany). The exchange with companies in practice is continued in the last semester when the students execute their own project at a cooperation partner from the chemical industry within their Bachelor Thesis.

An essential distinguishing feature of this study program in comparison to usual business engineer study programs as they are offered at universities is the program structure: chemistry and economic-related courses are not taught in parallel in the first semesters. In fact, the prospective business chemists spend the first two years together with the students of 'General Chemistry'. Two advantages are realized: by the full-time participation with natural sciences and chemistry, the students gain skills like pure chemists. Moreover, in the fourth semester they may decide if they want to continue in the eight-semester bachelor program 'General Chemistry' or if they want to choose the business-related courses in the fifth semester. Actually, several students make use of their opportunity to change the study program every year. Even some students of the study program 'General Chemistry' become business chemistry students in the fifth semester. Until the end of the fourth semester, the students have learned about the specifications and professional opportunities of both study programs and have exchanged experiences with students from higher semesters as well as alumni and professors and tutors.

The master study program is designed as a five-semester part-time study program (120 ECTS credit points). Since the focus is especially set at the business-related courses, the students get the opportunity to transpose their knowledge gained at university parallel to their professional activity in practice by the part-time structure.

We have gained several positive experiences with the study program 'Business Chemistry' in the last ten years. Since 20 student places at maximum are offered in the bachelor as well as in the master study program each year, the study groups are relatively small. Since about 70 per cent of the bachelor study program's graduates decide for a profession in the chemical industry after their completion and do not change to a consecutive full-time master study program, the summary for the bachelor study program is very positive up to now.

All students who finished the master study program decided for a professional career in the industry up to now. The Fresenius University of Applied Sciences does not offer a PhD after the successful completion of the Master Thesis.

In the future, we will further concentrate and sharpen the focus on practical and application orientation within the study program. We face a great challenge to sustain, support and improve the well-known chemical industry's innovation strength. In order to realize more start-ups in the chemical industry, more founders are necessary. Therefore, our goal is to educate students in chemistry and business administration , so that they are capable to see employment and entrepreneurship as two options for their life they can profoundly and consciously decide upon.

By combining the curriculum adjusted towards the entrepreneur and the program 'Idea2Business' we follow the aim to provide an enormous contribution to the foundations' dynamics out of the chemical industry and to realize more foundations.

Chemistry and Management at Ulm University – excitement about the future

Prof. Dr. Michael Hiete, Institute of Theoretical Chemistry and Chair of Business Chemistry, University of Ulm

Ulm University, which had its 50th anniversary last year, looks back at a history of more than 15 years in the consecutive program in chemistry and management. Founded in 2001 and supported with high enthusiasm over the years by Prof Gerhard Maas, the program steadily evolved and Ulm University has become, with more than 200 students, the second largest well-known site for these studies in Germany.

The spectrum of challenges and opportunities modern chemistry is faced with ranges from electrochemical energy conversion and storage to digitalization. Experts are needed to assess products and processes and to manage innovations. Therefore, knowledge and methods from both disciplines - chemistry and management - are necessary, as only a thorough understanding of the solutions chemistry can offer, combined with knowledge of assessment and planning methods, will allow successful management of processes, products, and companies.

The program in chemistry and management at Ulm University has strongly evolved over the past years, especially with the latest major reform dating from 2017. Surprisingly, each reform strengthened the role of management science in the program. As students starting their studies often do so without having a complete overlook of their choice of study program and are torn between starting a program in pure chemistry or in chemistry and management, the reform of 2017 offers to set foci in the last year of the bachelor program with varying shares of chemistry and management. This allows students, for example, to focus on topics at the interface between chemistry and management but also alternatively on chemistry, offering them the possibility to continue in the master program with chemistry. In addition, it has become also possible to integrate courses in chemical engineering. Set in stone, however, is the idea of starting with courses in both chemistry and management already in the first semester as this is thought to foster the thinking and understanding in and familiarity with the two disciplines right from the beginning.

A pivotal change for chemistry and management at Ulm University came along with the appointment of a professor for Business Chemistry in 2016, making Ulm University besides University of Münster the second university with a professorship specifically dedicated to chemistry and management. This appointment not only enriched the range of topics in research and education, it also allows a better integration of the two disciplines which in the past existed side by side demanding high integration efforts from the students. It is our hope that courses supporting interlinked thinking and dealing with problems at the interface stimulate and motivate students. The new professorship also enriched research and teaching by bringing in new areas, for example operations and especially sustainability management. In the past, chemistry was often associated with negative attributes, but today chemistry must be seen as key for a number of sustainable development goals addressed inter alia in sustainable chemistry. Sustainability has become a must-have for companies.

Motives for studying chemistry and management differ, but our experience shows that students appreciate not only excellent job opportunities and the challenge to work at the interface between two worlds, but also some more obvious advantages; for example, that a PhD is - unlike in

chemistry - not regarded as compulsory. We observe also other differences such as the fact that students in chemistry and management tend to prefer chemical sub-disciplines for their bachelor theses without typical lab work and often go abroad for their internships in industry.

Though rewarding, interlinking the two disciplines remains demanding. At Ulm University, the new situation created an enormous atmosphere of departure also reflected by many activities of the students. Summing up, Ulm University's chemistry and management program has grown and looks with optimism to the future. It is now time for the students to build more self-confidence from related disciplines such as business and industrial engineering.

Bachelor Business Chemistry in Regensburg: Expansion towards the South-East of the Country

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The University of Regensburg has been celebrating its 50th anniversary in 2017 and is proud of having grown to a total of 21,000 students over the years. The Faculty of Economics was one of the founding faculties, whereas chemistry, as part of the Faculty of Natural Sciences, joined one year later. Nowadays, chemistry and economics host about 4,000 students in several study programs covering bachelor's, master's and teaching degrees. Just in time for the anniversary, the two faculties decided to team up and develop a study program together. This decision was motivated by two reasons: (i) the growing interest of chemistry students in extra education in business administration as a side dish to their main course chemistry and (ii) our understanding that many students with an interest in chemistry do not intend to follow a strictly scientific path, but want to prepare themselves for a career in the chemical industry. Following the initiatives of other universities across the country, the BSc Business Chemistry at the University of Regensburg was born and started in the current winter term 2017/2018 with 50 students - one for every year of the university's existence. We certainly hope that the number of students will never fall behind the age of the university in the future.

The number of students in this first round of BSc Business Chemistry in Regensburg was surprisingly high given the fact that the time for advertising and marketing the new study program was just a few months. But it confirmed our notion that there is a considerable demand for this kind of interdisciplinary and tailored education in particular as no other university in Bavaria or the eastern side of Germany provides a similar offer. So far, there is no indication that this extra study program has led to cannibalism with respect to other chemistry programs as the number of enrolled students in those programs remained stable. The years to come will prove this right or wrong. Study programs in business administration are overbooked anyway in Regensburg as in most universities nationwide.

The curriculum of the BSc Business Chemistry is organized such that chemistry and business administration are taught in parallel from the first semester with special emphasis on business chemistry towards the end. The final connecting part of the curriculum is covered by colleagues from industry, who will share their experience and daily routines with our students. Moreover, the curriculum BSc Business Chemistry is designed such that students who recognize their true passion or a particular talent for straight chemistry or business administration along the way will get a chance to continue their bachelor's studies by entering the MSc Chemistry or the MSc Business Administration programs after fulfilling some extra requirements. It was our intention to make the study program as permeable as possible to all sides without relaxing academic standards.

Currently, we have very little experience with this new study program but we are very optimistic that the BSc Business Chemistry and the subsequent master's program will be attractive to young people with an interest in science and economics who are seeking a tailored education at the interface of the two disciplines.

