

Geosciences education at German universities

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Geoscientific education is offered by 31 German universities. Each year, about 4,000 first-semester students begin their bachelor's or master's studies and around 2,200 graduate with a bachelor's or master's degree. More than 90% of the bachelor's students continue with a master's course. Most graduates find employment in the applied sectors.

Apart from understanding 'System Earth', modern geosciences programmes contain more and more socially relevant topics, leading to a broad and complex terminology and study program offer. In this context, the new 'GUIDE' portal by EFG and BDG (Berufsverband Deutscher Geowissenschaftler, German Professional Association for Geoscientists) allows (prospective) students to easily compare available courses and provides a quick overview of geosciences education in Europe.

L'enseignement géoscientifique est proposé par 31 universités allemandes. Chaque année, environ 4 000 étudiants du premier semestre commencent leurs études de licence ou de maîtrise et environ 2 200 obtiennent un diplôme de licence ou de maîtrise. Plus de 90% des étudiants en licence poursuivent leur cursus en master. La plupart des diplômés trouvent un emploi dans les secteurs appliqués. Outre la compréhension du «Système Terre», les programmes de géosciences modernes contiennent de plus en plus de sujets socialement pertinents, conduisant à une offre de programmes d'études et de terminologie large et complexe. Dans ce contexte, le nouveau portail «GUIDE» d'EFG et de BDG (Berufsverband Deutscher Geowissenschaftler, Association professionnelle allemande des géoscientifiques) permet aux étudiants (potentiels) de comparer facilement les cours disponibles et offre un aperçu rapide de l'enseignement des géosciences en Europe.

La educación geocientífica es ofrecida por 31 universidades alemanas. Cada año, alrededor de 4.000 estudiantes del primer semestre inician sus estudios de licenciatura o maestría y alrededor de 2.200 se gradúan de dichas especialidades. Más del 90% de los estudiantes de licenciatura continúan con un curso de maestría. La mayoría de los egresados encuentran empleo en los sectores aplicados. Además de comprender el "Sistema Tierra", los programas de geociencias modernos contienen cada vez más temas de relevancia social, lo que conlleva una oferta de programas de estudios y terminología amplia y compleja. En este contexto, el nuevo portal "GUIDE" de EFG y BDG (Berufsverband Deutscher Geowissenschaftler, Asociación Profesional Alemana de Geocientíficos) permite a los potenciales estudiantes comparar fácilmente los cursos disponibles y proporciona una descripción general y rápida de la educación en geociencias en Europa.

From geology to geosciences and beyond

Education in Earth Sciences has a long tradition in Europe (Wagenbreth, 2015). Over time, classical geo-

logical disciplines were complimented by additional interdisciplinary sub-disciplines such as environmental geology or marine geology. New universities were established and thus, more than 30 higher education institutions in Germany came to offer study programmes such as like geology, palaeontology, geophysics and/or mineralogy. As part of a larger restructuring process at German universities in the 1990s, the four classical subjects were combined at many universities into a new subject, Geosciences, and so we understand geosciences as a subject which has emerged from these four basic disciplines.

The two-tier system: Establishing the Bologna reform

Like everywhere in Europe, the old Diploma programmes were converted into bachelor's and master's degree programmes during the Bologna Reform at the beginning of the new millennium. All study pro-

grammes are modularized and equipped with ECTS credit points. According to the European standard, a German bachelor's programme usually has a standard duration of 3 academic years (or 6 semesters) and can be continued by a 4-semester (or two-year) master's programme. Another 3+ years are invested by students seeking a doctorate. Research institutions, public authorities and the geosciences faculties or institutes themselves offer attractive opportunities for a PhD position and further career steps into science. Most PhD students are employed at Universities or research institutions as research assistants with a 50-75% remuneration of research assistant positions.

Bachelor programmes in geosciences in Germany are commonly admission-free. Only a general university entrance qualification and sufficient knowledge of the German language is needed in order to be accepted. The master programmes, on the other hand, have very different and augmented high specialist admission require-

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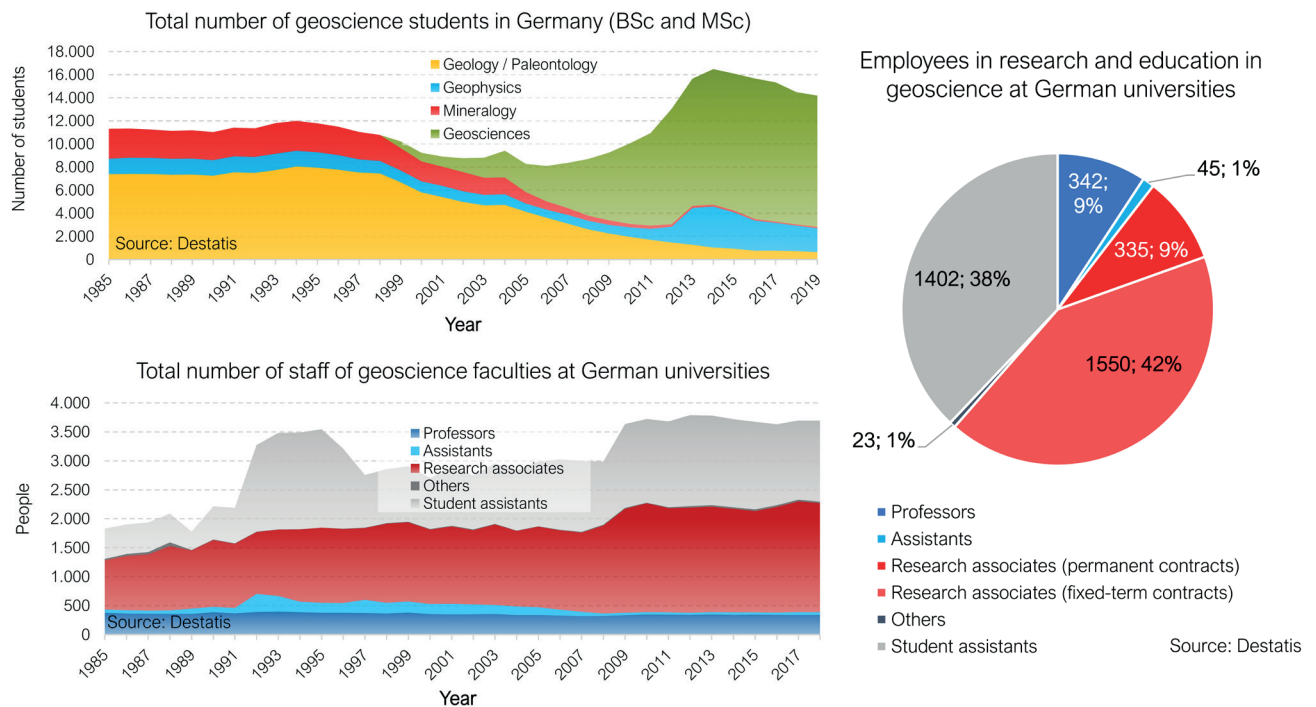


Figure 1: Students, teaching and research staff in geosciences in Germany (modified after Merschel, 2020).

ments. Of 75 master programmes geosciences faculties and institutes provide, 31 are offered with English as the language of instruction – increasing tendency. In contrast, only one bachelor programme is currently offered in English and a second one starts in 2021 (see Figure 3, violet points).

In general, German universities do not charge tuition fees for European citizens – except at the few private universities. The structure, curriculum, and the infrastructure of all study programmes in Germany are accredited in 7-year intervals by accreditation agencies or within the evaluation processes of system accredited universities. This high-level quality assurance measure guarantees the quality in terms of study-ability, study profile as well as employability and offers at the same time a competence-oriented control of German geoscientific study programmes among themselves.

Since the academic self-administration of the universities also requires participation of students, the student elect representatives who are organized in student councils. They are representing students in university policy bodies, helping with e.g. structural problems, and organizing freshmen introduction weeks. The umbrella organization of the student councils in geosciences is a not-for-profit association called “GeStEIN – Geoscientific Student Experience and Interests Network e. V.”. Among other things, GeStEIN also develops proposals for the further development of geoscientific

education. Furthermore, many universities host local student chapters organized in a Germany-wide network focusing on connecting German geoscientific companies with students.

Geoscientists at research institutions and universities and the German labour market in geosciences

Students with a bachelor’s degree are considered to have achieved their first professional qualification and can enter the labour market. However, more than 90% of the undergraduate geoscientists continue in a master’s programme to receive a higher graduate level before starting their professional career. Even though the situation in geoscientific research at universities and non-university institutions for entering a PhD position is good, only a very small percentage of the PhD graduates are able to pursue an academic career due to the lack of permanent positions in academia in Germany. The German Professional Association for Geoscientists (BDG) calculates that only 2–4% of geosciences students entering universities can later on count on employment in research and teaching. Of around 30,000 professional geoscientists in Germany, a little less than 10% are working at universities or research institutions, most of them (>80%) in non-permanent positions (Figure 1).

About 9% of the teaching and research

staff in Geosciences are employed as professors - a share that has not significantly changed for decades. The share of research associates is currently just over 50%. In terms of numbers, it has stagnated over the last 10 years, as has the large number of student assistants and part-time workers, who tend to be involved in research rather than in the training of geosciences students. A comparison with the development of the student statistics in geosciences, as displayed in the upper bottom line graph in Figure 1, clearly shows that the low remaining portion of lecturers were facing a strong increase of geosciences students between 2007 and 2014. At present, ~14,000 students are being supervised at geoscientific faculties and institutes by 342 professors and 1,900 research associates. 82% of the research associates are non-permanently employed (including qualification positions such as PhD students). Looking at the hierarchical structure of the universities hosting geosciences, we identified only eight geosciences faculties – i.e., equipped with all positions of academic self-administration. At all other universities, the geosciences are affiliated with the mathematics and natural science faculties or even with other faculties.

In 2019 nearly 1,000 bachelor’s and 1,200 master’s degree students graduated in geosciences (Source: Federal Statistical Office Destatis). These figures reflect the slight decline in the number of first-year bach-

Employment Sectors of Geoscientists in Germany

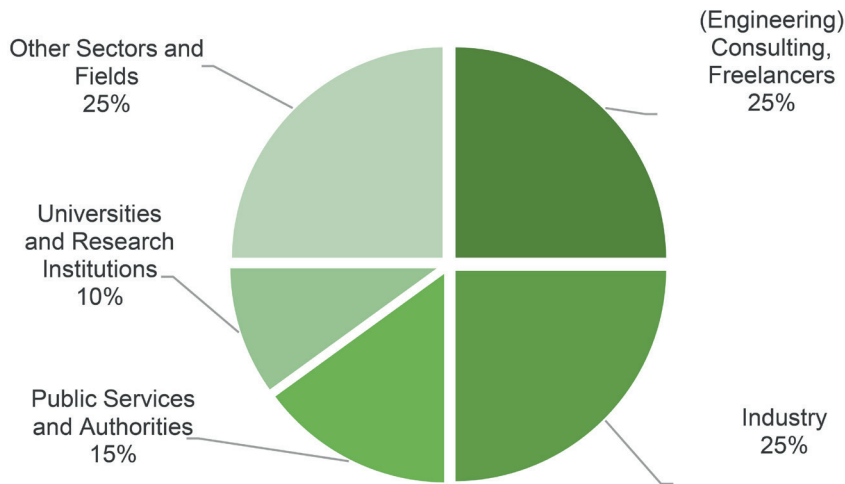


Figure 2: Approximate proportions of geoscientific employment in Germany (Merschel et al., 2020).

elors' students in 2016 and indicate as well a certain number of subject changers and international students entering geosciences for a master's degree. The gender proportion among the geosciences students (including PhD students) in Germany ranges between 40 to 45 % women. The majority of those seeking a job find employment in the applied professional fields of geosciences (Merschel et al. (2020) (Figure 2). They are mostly employed in geo-consulting companies, in industry or work as freelancers (together 50%). The most-common sectors are engineering geology, hydrogeology, treatment of contaminated sites and deposits, raw materials and resources or the energy sector (Fahry-Seelig et al., 2012). A further 15% of geoscientists are employed in governmental offices and authorities. The remaining 25% of those who once received a geoscientific education are now working in other professional areas that are either not related or only distantly related to geosciences. The current unemployment rate in geosciences in Germany is 4.7% (pre-Coronavirus pandemic).

Geosciences Faculties and Institutions

Today, the term geosciences is the most common at German universities. There are 22 bachelor's and 21 master's programmes named Geosciences or Applied Geosciences. In contrast, study programmes still called geology or geological sciences are just located at five universities (Figure 3, yellow points). Similarly, palaeontology is only offered as a master's program at one university (Figure 3, red point). Mineralogy no longer exists as a separate subject, but

it still plays a significant role in study programmes dedicated to the materials science of natural solid-state materials. Geophysics is still represented as an individual bachelor' and/or master' programme at eight universities across Germany (Figure 3, green points).

Currently 31 geosciences faculties and/or institutes exist in Germany. The high number of universities in comparison with our European neighbours stems from historical reasons and is caused by the German

federal system and is also related to the needs of the German labour market, which still demands a relatively high number of engineering specialists all over the country. In addition, many of the big German research associations like Leibniz, Senckenberg or Helmholtz also host geoscientific sections or departments whose staff is involved in both research and teaching. In areas with closely neighbouring geoscientific institutes, many universities have formed research alliances, some of which also cooperate in teaching, thus offering joint degree programmes or opening their courses to students from cooperating faculties. Examples are the ABC/J Geoverbund network between the universities of Aachen, Bonn, Cologne and the research institution Jülich, or the Munich Geocenter of the two universities LMU and TUM. A "role model" for study programmes with international cooperation partners and industry is the joint master's programme in Applied Geophysics offered by RWTH Aachen, ETH Zurich and TU Delft.

Geosciences curricula - similarities and specifics

One of the most important pillars in geoscientific training continues to be field work. Geological mapping and field exercises are still the main practical parts of German geosciences education, as required by the Tuning Project (2009). Apart from



Figure 3: Geosciences faculties and institutes at German universities (modified after Schlüter et al., no year). Colour code: in yellow - Geology; red - Palaeontology; green - Geophysics, violet - BSc in English.

GUIDE – a European portal to compare geoscientific study programmes

In order to provide students with a quick and comprehensive overview regarding the curriculum and specialisation areas in geosciences, the BDG initiated the GUIDE portal (www.geoscience-studies.org) in collaboration with the European Federation of Geologists (EFG). The GUIDE portal was rolled out in July 2020 and allows the comparison of study programmes in geosciences in Europe by listing all participating universities with their study contents in ECTS credits. GUIDE contains bachelor's as well as master's programmes at each study location, divided into the different specialisation areas such as e.g. sedimentology, petrology or hydrogeology. Users can choose the study locations and/or the specialisation areas they are interested in and can compare in a visually appealing way how many credit points (CPs) are offered in the respective study areas.

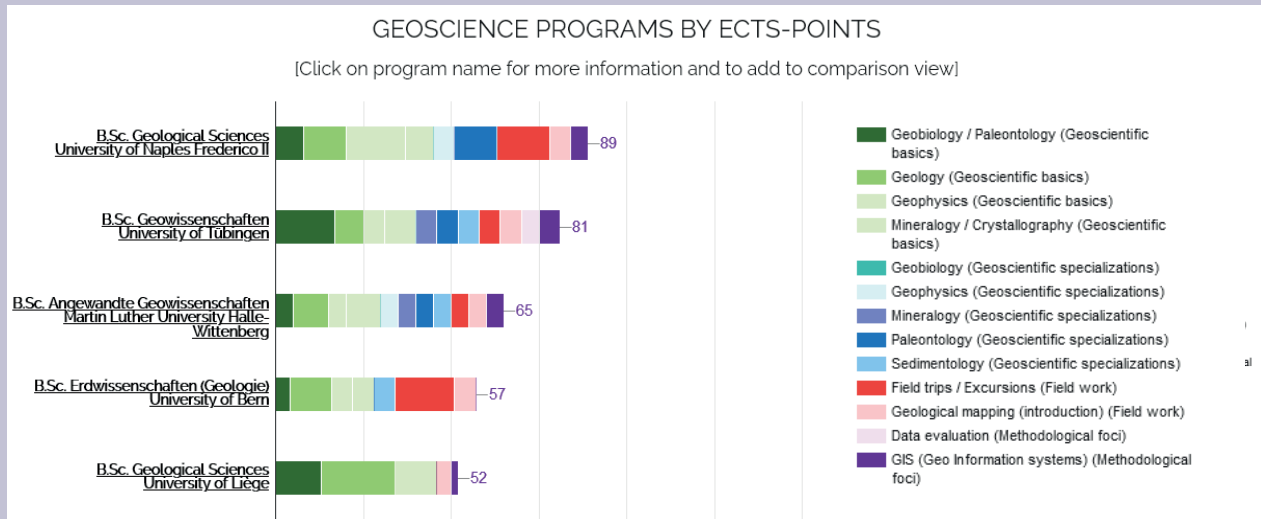


Figure 4: Screenshot GUIDE: Selection of bachelor's programmes with the most credits in specified subjects.

The information offered by GUIDE originates from study deans, programme coordinators and/or students of each participating institution. They enter the ECTS credits of their study programmes following the rule that each CP of a programme must appear, but only once, in one of the categories.

In recent years, a first version of the comparison portal within the geosciences education landscape of Germany enjoyed great demand. The good response and the unique proposition of this offer prompted the BDG to expand the portal to the European level. EFG joined this initiative, and GUIDE has also received support from the EFG Horizon2020 project 'International Network of Raw Materials Training Centers' (INTERMIN). GUIDE, a unique comparison portal for geoscientific study programmes in Europe, is available from summer 2020. Access for (prospective) students (and other interested parties) is free of charge, and so is the entry of study programmes. We urge universities across Europe to add their programmes to this database. For further information and for getting a university user account, please contact mail@geoscience-studies.org.

understanding 'System Earth', the laboratory practice, analytical methods and more recently data management or geomathematics and modelling courses including software applications turn out to be important parts of the curricula. With a basic mandatory university education in mathematics, physics, chemistry and often biology within the bachelor programmes, German geoscientists have a good basis to quickly and competently familiarize themselves with a variety of scientific issues. The bachelor's as well as the master's degree is completed with a scientific thesis, which in most cases needs to be defended by the students, similar to a PhD thesis, leading the students to independent project management and a scientific workflow.

Direct insights into professional life are guaranteed by internships lasting between four and twelve weeks, which are part of

the curriculum at most universities in Germany. Furthermore, many students take advantage of the opportunity of integrating a stay abroad into their studies, either as an internship or as a study exchange semester (e.g. via ERASMUS+ or any other international exchange programme).

While the geosciences curriculum of bachelor's programmes is supposed to be broad, the master's programmes offer the opportunity to specialise. The spectrum of specialisation ranges from e.g. applied geosciences to biogeosciences, climate system science, geophysics, georesources, geohazards, geoenergy, mineralogy and geomaterials, and marine geosciences. However, the geoscientific educational landscape in Germany continues to change (cf. Wefer, 2010). Bachelor's programmes such as Geosciences and Applied Geosciences are still the majority, but we are noticing a tendency

towards more interdisciplinary programmes with adjacent scientific disciplines included. Environmental topics, climate, ecology and biogeosciences are gaining ground, as well as combined programmes with a special focus on management and sustainability. While this tendency is increasing the disciplinary diversity among geosciences graduates, it causes a loss in sharpness of their competence profiles, with negative impacts on their employability e.g. in the engineering sector, where other professions immediately fill these gaps.

Another consequence of the increasingly divers geosciences education landscape in Germany is that most prospective students (either after finishing their high-school education or after graduating with a bachelor's degree) face challenges obtaining a clear and holistic overview about the available study programmes in geosciences. It is

impossible to become familiar with the quite different curricula of all geoscientific study programmes before making a decision. From the quality assessment surveys, we know that the students' decision on where to study is mainly based on where they live or would like to live (bachelor's) or the research profile of a particular geosciences faculty (master's). In consequence, many students do not make use of the extensive mobility options that arose from the Bologna Reform and may not always study within the programmes whose curricula suit their personal interest best.

Future challenges in German geosciences education

Geosciences education in Germany is excellent, diversified and well positioned – nevertheless future challenges lie ahead. In recent years, most universities offering bachelor programmes in geosciences have face a gradual decrease in entrants (Fig. 1). While small cohorts allow better targeted support for students, a continuously decreasing number of students can cause severe problems for small institutes in maintaining their offers. Combined with the retirement of teaching staff, this trend

especially endangers the continued existence of teaching and research groups in the so-called 'small disciplines,' e.g. crystallography, mineralogy and palaeontology.

Nevertheless, we welcome the development of geoscientific education towards a science that is becoming more and more oriented on socially relevant needs by opening up to other disciplines within Earth System Sciences. However, the entire breadth of geosciences education during the bachelor's programme that provides the required scientific and applied basis for further academic training will also be necessary in the future. Based on this broad education basis, the highly diverse master's programmes offer students the possibility to expand their scientific expertise further.

Although a rising number of graduates in geosciences are later confronted with and work on the most pressing societal issues such as global climate change, energy and raw material supply, as well as geo- and environmental risks (EFG, BDG, & GSL, 2015), most curricula do not yet include aspects of geoethics. Geoethics training, e.g. how geoscientific content should be communicated, would empower our alumni to work more effectively at the interface of future geoscientific and societal issues.

Even if the large number of graduates in geosciences compared to previous decades has been absorbed by the good economic situation over the last years, we must be concerned about the uncertain economic development connected with the COVID-19 pandemic. The balance between the number of graduates and the labour market demand needs to be maintained. In any case, additional efforts are necessary, e.g. to strengthen the role of geosciences in school education, which in turn can help to create greater visibility for geosciences.

Moreover, also a changing labour market requires us to adapt geosciences study programmes on a regular basis. We are currently witnessing how the field of hydrocarbon exploration is becoming less important as a potential employment sector, whereas other socially relevant areas are evolving, e.g. environmental geosciences, sustainable resource geology and other topics like carbon storage, nuclear waste management and the use of renewable energy resources. In addition, we must face up to the need to digitise our study and working lives. Modern study programmes are on the way to address these topics to ensure the training of qualified specialists capable to tackle future issues in geosciences.

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