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Evaluation of structured doctoral training programs in German life sciences: how much do such programs address hurdles faced by doctoral candidates?

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Introduction: Ways to improve the quality of doctoral education are debated internationally. In Europe, the United States, and other countries, there have been policy initiatives to address these. One approach has been the implementation of so-called structured doctoral training programs (doctoral programs) including formal structures such as courses, supervision agreements, external examiners for grading the thesis. However, there is little known about how doctoral programs implement the debated structures. As a result, the question arises whether existing programs already address the challenges of doctoral education and implement policy demands.

Methods: In this study, we evaluated the structure of 82 life science doctoral programs in Germany in a document analysis and a survey of program experts. We focused on (1) interdisciplinary aspects and (2) the international orientation of these programs. We evaluated the (3) courses offered, (4) formal characteristics of supervision, and (5) examination regulations of the doctoral programs.

Results: The results showed that the doctoral programs already address these five aspects to some extent. However, there is variability as a function of institution and details of policy demand realizations are very heterogeneous. Some doctoral programs provide opportunities for interdisciplinary cooperation, but only few promote international orientation. Offered courses cover some relevant academic skills, but courses on, e.g., teaching, open access and public outreach are still rare. Structured regulations on supervision, e.g., through regular meetings and supervision agreements, are also rarely implemented. Lastly, most supervisors remain strongly involved in examining doctoral theses.

Discussion: We conclude that there is still a crucial need for improvement of doctoral programs through more extensive implementation of policy demands. We detail cross-national and -disciplinary practical implications for coordinators of doctoral programs.

KEYWORDS

doctoral programs, interdisciplinary research, internationality, formal learning, supervision, examination

1. Introduction

Improving doctoral education is relevant internationally. Worldwide, there are different forms of doctoral education and a variety of supportive structures that are debated, as these may influence the varying quality and success of doctoral education (Gardner, 2010). In the United States, policy makers demand improvement of heterogeneous conditions in doctoral education to enhance international competitiveness (Kehm, 2006; Schneijderberg, 2018). Some institutions, such as the Carnegie Foundation and the Mellon Foundation have started initiatives (e.g., the 'Carnegie Initiative on the Doctorate'; 'Graduate Education Initiative', respectively) with the goal of ultimately providing a stronger structure for doctoral programs (Nerad, 2008; Schneijderberg, 2018). In the humanities, the Mellon Foundation's 'Graduate Education Initiative' is aimed at providing structures helping more doctoral candidates conduct their doctoral studies in brief time slots, while maintaining education of high quality, even when the number of candidates increases (Ehrenberg et al., 2010; Schneijderberg, 2018). To reach these goals, Ehrenberg et al. (2010) identified various strategies of the initiative for doctoral education (e.g., courses on research methods and attendance at them). So far, efforts in doctoral education mainly shaped the initial doctoral phase when doctoral candidates have completed courses. However, support for writing the doctoral thesis should be further improved in the United States (Ehrenberg et al., 2010; Schneijderberg, 2018). Other countries, such as Russia and Japan, have taken steps to improve doctoral programs as well (e.g., Nerad and Heggelund, 2008; Maloshonok and Terentev, 2019). Programs in Russia have transitioned to a more formally structured doctoral education, similar to that in the United States. However, the Russian transition was merely on a formal level, resulting in, e.g., courses on topics already trained in bachelor and master courses (Maloshonok and Terentev, 2019). Furthermore, doctoral candidates in Russian doctoral programs were still mostly supervised only by one supervisor (Bekova and Terentev, 2020). In Australia, doctoral education is demanded to increasingly prepare doctoral candidates also for careers outside academia (e.g., in industry). Therefore, professional doctoral programs should be further improved and introduced (McWilliam et al., 2002). Various efforts have been taken to improve doctoral education internationally, but it should be further improved. Issues in doctoral education are debated in many nations. Since doctoral education is embedded in national structures and traditions of higher education (Ambrasat and Tesch, 2017), it is necessary to investigate doctoral education within national conditions. To do so, we are focusing exemplarily on German doctoral education considering German conditions while also having international issues of doctoral education in mind.

In Germany, the lack of international competitiveness of doctoral graduation results from a varying quality of doctoral studies (e.g., GSHC, 2002). While an increasing number of students start a doctorate, there is a high drop-out rate (e.g., BuWiN, 2017, 88–92). Though, access to a doctorate seems to be already improved since an increasing number of qualified students can enter a doctorate. However, conditions during the doctorate seem to be still an issue—indicated by the high number of drop-outs. Besides general issues of varying doctoral studies' quality and lacking international competitiveness, there are subject-related issues in doctoral education. Especially in German life sciences including medicine, biology, and further natural sciences, quality and conditions of doctoral education are discussed widely. In medicine, the quality of doctoral education is often criticized for many medical doctoral candidates having already completed their doctorate before receiving their first medical degree. Consequently, the quality of many doctoral theses is not of high scientific standard, as some medical theses do not make an original contribution to research (GSC, 2011). In biology, issues in conditions for conducting doctoral studies are debated when biological doctoral candidates have to research in several short-time contracts while doctoral graduation in biology is expected for many employments outside academia (Hornbostel and Simon, 2010; Plasa, 2014). In general, policy initiatives require an improvement in German doctoral education (HRK, 2012; BuWiN, 2017). Nationwide implementation of structured doctoral training programs (doctoral programs) is a central approach to address and overcome hurdles of previous doctoral education (e.g., HRK, 2012).

Various studies on international and national level have investigated the structure of doctoral programs emphasizing the relevance of further improving doctoral education within these programs internationally (e.g., Ehrenberg et al., 2010; Schneijderberg, 2018; Maloshonok and Terentev, 2019; Lachmann et al., 2020). In Germany, for example, several policy demands for improving doctoral education are still not yet implemented (e.g., Lachmann et al., 2020). Recent data on doctoral education in German doctoral programs is lacking although in certain fields, such as the life sciences, the majority of doctoral students is enrolled in doctoral programs (BuWiN, 2021). Therefore, this paper is aimed at closing the research gap on the current status of improving doctoral programs. Since the life sciences are pioneers in implementing doctoral programs, we will focus on this field.

In this study, we review the approaches of German life science doctoral programs and investigate to what extent these programs fulfil the recommendations and needs for improving doctoral education. Life sciences include branches of natural sciences such as biology, which center around understanding life, but also include applied research fields. Biology and medicine are the most prominent life-sciences-fields regarding doctoral education as in both a doctoral graduation is considered as standard for entering a successful career (Hornbostel and Simon, 2010). Although the traditions of doctoral education differ quite a lot between biology and medicine, implementing doctoral programs is a means for improving doctoral education in all life science fields as it can address different issues at the same time. In medical fields, doctoral programs were specifically implemented to improve the often criticized scientific quality in doctoral studies to reach a level that is comparable to other life sciences fields, in addition to general issue of doctoral education, such as low quality supervision, found in many fields. Life science research is also often interdisciplinary and not tied to one specific subfield within the life sciences. Doctoral programs are often drivers for fostering interdisciplinary life science research. Given the general purpose of doctoral programs, i.e., structuring and formalizing doctoral education for aligning doctoral education on a high level (Ambrasat and Tesch, 2017), and the interdisciplinarity of the life sciences (e.g., Hellweg et al., 2017; Qin, 2017), this paper includes a variety of doctoral programs within the life sciences in Germany. We first present an overview of the German doctoral education system in the life sciences (section 2) as a basis for the following descriptions and analyses. Additionally, we briefly describe intended improvements of doctoral education through the implementation of doctoral programs (section 3)—here,

we both address an international perspective as well as a German perspective. We focus on five chosen aspects of doctoral education in such programs: interdisciplinarity (section 3.1), internationality (section 3.2), coursework (section 3.3), supervision (section 3.4), and examination (section 3.5). After specifying the research question (section 4), we describe our methods including sample, design, and analyses (section 5). Both results (section 6) and discussion sections (section 7) were divided in five subchapters discussing each chosen aspect of doctoral education each. Finally, we suggest some practical implications for future doctoral programs (section 8), debate limitations as well as future research (section 9), and end with a brief conclusion about implemented structure and formalization of doctoral education in life science doctoral programs (section 10).

2. The German doctoral education system in the life sciences

Before 1999, as was the case in several European countries, German doctoral candidates completed their doctoral studies in a traditional master-apprentice-model. Usually, one professor and occasionally one or more postdocs supported the candidate during their entire studies (Berning and Falk, 2006). There were some shortfalls in this model though, such as lacking quality control and formal learning opportunities, a dependence on the goodwill of the supervisor, and lacking competitiveness of German doctoral graduates (e.g., GSHC, 2002).

With the 'Bologna-Declaration' of 1999, the European higher education system drastically changed in order to become more competitive globally (The European Higher Education Area, 1999; Hauss et al., 2012). Thereafter, doctoral programs have been implemented to address and overcome hurdles of the traditional master-apprentice-model in the most European countries (e.g., Sursock and Smidt, 2010; HRK, 2012). In the last decade, the number of German doctoral programs has increased (BuWiN, 2017). Currently, most German universities offer doctoral programs, as well as master-apprentice-models, with various hybrid approaches in between. Consequently, the degree of structure during an individual candidates' training cannot be simply classified as that of a doctoral program versus the traditional master-apprentice-model (Martius et al., 2014; Lachmann et al., 2020). However, there is a clear shift away from the pure master-apprentice-model to doctoral programs and hybrid approaches (Schneijderberg, 2018; BuWiN, 2021), emphasizing the relevance of doctoral programs as structural approaches for doctoral education. Furthermore, the PhD as an international doctoral degree was introduced in Germany besides the existing classical German doctoral degrees (e.g., Dr. med.[1] for medical graduates or Dr. rer. nat. for natural science graduates). In order, to facilitate the dissemination of results of this German sample to an international audience, we present a brief overview of the German higher education system in the life sciences. Life sciences as an interdisciplinary field brings together several research fields interested in understanding life, including medicine, dentistry, biology, chemistry, and a large number of other natural sciences. At a typical German medical faculty, a state exam in medicine or dentistry qualifies students to start their doctorate; they will typically graduate with a Dr. med. (medicine) or Dr. med. dent. (dentistry) degree. At natural science faculties, in contrast, a master's degree in biology, chemistry, and related fields qualify students to pursue a Dr. rer. nat. Furthermore, there are other specific doctoral degrees dedicated to specific fields, such as Dr. ing. for engineering, Dr. agr. for agricultural sciences or Dr. phil. for humanities and social sciences, which can be earned in their respective faculties. Since life sciences are an interdisciplinary field, students without a dedicated medical degree can also study for a doctorate in medical faculties, but will receive different forms of doctoral degrees (Dr. rer. biol. hum., Dr. rer. medic., and Dr. nat. med.). Figure 1 gives an overview about doctoral degrees available in the life sciences in the German higher education system.

3. Intended improvement of doctoral education provided through doctoral programs

Doctoral programs are aimed at improving doctoral education through implementation of support structures for doctoral candidates. To understand whether policy recommendations for implementation of doctoral programs have been successful, we must first understand what kind of improvements in doctoral education are seen as necessary, in Germany and internationally.

There is a large body of literature on doctoral programs. Besides policy demands and suggestions on the improvement of doctoral education through implementation of doctoral programs (e.g., The European Higher Education Area, 1999; GSHC, 2002; HRK, 2012), there are essays on ideas for improvement (e.g., Marx et al., 2016) and literature reviews (e.g., Campbell et al., 2005; Vanstone et al., 2013; Bekova and Terentev, 2020). Furthermore, there is a variety of qualitative (e.g., interviews, case studies) and quantitative studies (e.g., document analyses, surveys) as well as studies using mixed methods in various national contexts (e.g., New Zealand, Hong Kong, England, among others) and in various disciplines (e.g., business, education, natural science, among others) (e.g., Kwan, 2010; Ward et al., 2011; Fenge, 2012; Borders et al., 2014; Ambrasat and Tesch, 2017; Kidman et al., 2017). Previous literature has focused on many issues of doctoral programs such as internationality (e.g., Jacob and Meek, 2013; Cutri, 2019), interdisciplinarity (e.g., Qin, 2017; Doody, 2020), courses within a curriculum of doctoral programs (e.g., Card et al., 2016), supervision approaches (e.g., Kidman et al., 2017), examination processes (e.g., Nerad, 2008; Schneijderberg, 2018), requirements for access to doctoral programs (e.g., Enders, 2005), and organizational structures of different doctoral programs (e.g., Korff and Roman, 2013) as well as the duration of the doctorate and financial resources (e.g., Schneijderberg, 2018) and many more. Additionally, some papers describe the approach of specific doctoral programs [e.g., SpaceLife (Hellweg et al., 2017)]. Considering the vast number of relevant and important topics for the understanding of an improvement of doctoral education and following similar studies (e.g., Ambrasat and Tesch, 2017), we focus on five central aspects of doctoral programs to provide an adequate insight into the structure of doctoral programs and introduce them in the following sections: (1) interdisciplinary aspects, (2) international orientation, (3) courses offered, (4) supervision, and (5) examination in doctoral programs.

1 See Table 2A in the Appendix for an overview about the abbreviation meanings of German doctoral degrees.

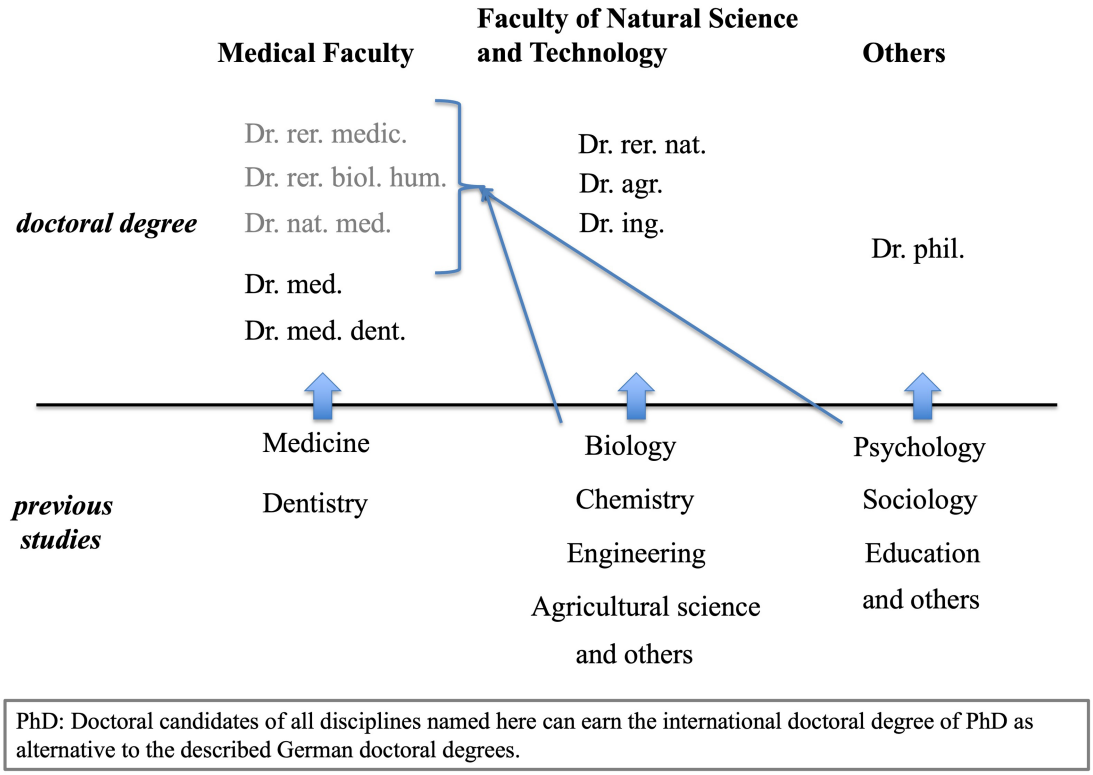

FIGURE 1
Overview of doctoral degrees available in the life sciences in the German higher education system. Previous studies and German doctoral degrees are categorized by degree-awarding faculty (special cases in doctoral degrees are written in grey).

3.1. Interdisciplinary aspects

Doctoral education should prepare candidates for several academic tasks. Among networking and collaborating (Kyvik, 2013), working in interdisciplinary cooperation is an important skill for scholars, although it can also be problematic (e.g., Enders, 2005; Manathunga et al., 2006). E.g., different research traditions or approaches can lead to conflicts between scholars. Previous studies indicated, there is still a need for improvement of interdisciplinary doctoral programs (Manathunga et al., 2006). Preparation of doctoral candidates for interdisciplinarity in research is internationally requested (Golde and Gallagher, 1999; Vanstone et al., 2013; Doody, 2020). In Germany, doctoral candidates valued already implemented interdisciplinary approaches (Enders, 2005). But with further improvement of interdisciplinary learning, doctoral programs can provide learning opportunities through cooperation between different research fields. Fostering interdisciplinary approaches in doctoral programs is both an international (Nerad, 2008) and German demand for improving doctoral education (Enders, 2005).

3.2. International orientation

Lacking competitiveness of doctoral education in an increasingly globalized world is widely debated in Germany and internationally (Kehm, 2006; Nerad, 2008; Hauss et al., 2012; Schneijderberg, 2018). International experiences during doctoral studies can foster skills of international scientific networking and intercultural understanding (Jacob and Meek, 2013; Cutri, 2019). To address the lack of competitiveness, doctoral programs are aimed at making doctoral education more competitive through internationalization. For increased international orientation, doctoral programs should facilitate enrolling of international students to assist them in completing their doctorate abroad. Additionally, most of the courses offered should be in English regardless of the respective national language (e.g., Berning and Falk, 2006). It is already widely implemented that courses are in English and the thesis itself is written in English, too, due to international scientific research in English (Bernstein et al., 2014). However, courses in English are also debated when national languages as scientific language have its place in scientific discourses as well—e.g. at a national level (Ammon, 2006; Meneghini and Packer, 2007). Terminology of the discipline in the national language is just as important as international terms in English—especially for an increasing number of doctoral graduates working in industry, business or other workplaces outside academia (e.g., Braun and Hadwiger, 2011; Germain-Alamartine et al., 2021). Given the extended purpose of doctoral programs to prepare candidates for both scientific and non-scientific careers (e.g., McWilliam et al., 2002; Berning and Falk, 2006; Nerad, 2008), the integration of courses in English as well as in the national language may be beneficial. Here, we focus on implemented courses in English as innovation and hint for internationality of doctoral programs. With courses in English and offers for international candidates, doctoral programs can prepare their doctoral candidates to succeed in competitive international science as well as in

competitive contexts outside academia which have also become more international due to globalization.

3.3. Courses offered

The various structures and quality of doctoral education led to non-standardized outputs of doctoral education. Internationally, the implementation of course programs differs widely—e.g. in the U.S., there is a variety of courses offered and requirements for their attending by graduate students (Nerad, 2008), while in Russia, courses as structured learning opportunities involve both doctoral students and administrators (Maloshonok and Terentev, 2019). In Germany, opportunities for learning critical skills of independent scientific research during doctorates still range from informal to formal learning (Martius et al., 2014; Lachmann et al., 2020). Furthermore, German doctoral programs differ widely in offering different types and numbers of courses (Hauss et al., 2012).

In order to address this problem, there are international and German demands for more formal learning opportunities (courses, workshops, and the like) in doctoral programs (Ehrenberg et al., 2010; HRK, 2012). In general, learning in doctoral programs should embrace disciplinary, interdisciplinary, general scientific, and key competences as well as that for practice and employment outside of academia (e.g., Enders, 2005; Berning and Falk, 2006; Nerad, 2008; Ehrenberg et al., 2010). Nevertheless, qualifying doctoral candidates for independent scientific work should remain the central aim of doctoral education (GSC, 2011).

3.4. Supervision

Mentoring and supervision of doctoral candidates by a single supervisor led to dependence on goodwill and engagement of that person. This is discussed as a problem internationally (e.g., Al Makhamreh and Stockley, 2020) as well as in the master-apprentice-model in Germany (e.g., Schneijderberg, 2018). To address this issue, doctoral programs should provide several supervisors, besides mentors and committees for supporting doctoral candidates (e.g., Berning and Falk, 2006; GSC, 2011). Having several supervisors can reduce dependence of the candidate on a particular supervisor, strengthen opportunities for socializing as well as providing more support than only one supervisor can offer (Jones, 2013), owing to the increased area of expertise covered by several supervisors (Hauss et al., 2012). However, a large number of supervisors are associated with concerns on both sides and could negatively affect satisfaction with supervision owing to its increased complexity, stemming from different ways of solving academic problems, and a larger number of time-consuming meetings (Hauss et al., 2012; Olmes-López and Sunderland, 2017).

Also related to supervision, and identified internationally and in Germany, is how doctoral candidates serve as low paid researchers or as lecturers (Walker, 2008; Schneijderberg, 2018). Therefore, research on doctoral projects can often only take place outside of normal work hours. Doctoral programs are expected to solve this problem by introducing extensive supervision agreements that include obligations and rights of both doctoral candidates and supervisors, e.g., regular meetings to ensure quality of doctoral education (GSC, 2011). However, previous findings still identify a discrepancy between recommendations for and implementation of supervision agreements (Lachmann et al., 2020).

3.5. Examination

Lacking transparency and consistency in assessing doctoral theses is a crucial point discussed internationally (Jones, 2013), but also in German contexts: in Germany, the predominate mode of reviewing a thesis is that of supervisors evaluating the doctoral thesis and determining the grade (GSC, 2011). For example, at a faculty of biology at a German university, the supervisor as well as a second examiner review the doctoral thesis and suggest if the thesis should be accepted, revised or rejected as dissertation. In this step, they propose a grade. Afterwards, a commission of further researchers of the faculty read the thesis due to review these suggestions. They can recommend a different grade. Finally, the dean of the faculty set the grade based on the suggested grades (LMU, 2016). However, still mostly the main supervisor suggests the grade for the doctoral thesis and the other examiners suggest if this suggested grade is appropriate. Though, even when some other examiners are involved in reviewing a doctoral thesis, the main supervisor still prevails the examination process. This approach bears several risks for inconsistent assessment. When doctoral candidates do their research in their supervisor's projects and have published papers with them, and if these are the basis for assessment, then supervisors evaluate their own research and supervision. This can lead to further conflicts of interest, e.g., supervisors may tend to evaluate a thesis as highly as possible to increase their own chances of raising further research funds. Doctoral programs may help to reduce these risks when more than one supervisor supports doctoral candidates during their studies and by having external examiners contribute to the evaluation of doctoral theses (Kehm, 2006). Doctoral programs may even exclude supervisors from the examination processes altogether (GSC, 2011).

4. Research question

The number of doctoral programs is generally increasing in Germany (BuWiN, 2017), and in the life sciences many students complete their doctoral studies enrolled in such programs (BuWiN, 2021). There are many suggestions on how doctoral programs should provide clear and explicit structure to doctoral education, with the goal of increasing the efficiency and quality of doctoral studies (e.g., GSC, 2011; HRK, 2012). However, implementation of structure in doctoral programs is still very heterogeneous—especially in the life sciences (Martius et al., 2014; Schneijderberg, 2018; Lachmann et al., 2020). There is already a lot of research on doctoral education in programs (see section 1.2). However, many studies analyzed data from surveys and only rarely document analyses (e.g., Kwan, 2010). Research on the current state of implementing published policies in life science doctoral programs is rare especially based on document analysis. Therefore, this study is aimed at investigating the following research question:

To what extent do regulations in German doctoral programs in the life sciences provide significant structure in

1. interdisciplinary aspects,
2. international orientation,

3. courses offered,
4. supervision,
5. and examination?

Here, we focus on the named five aspects because we want to take a closer look at these as examples as they provide a good profile of the programs' structuring and formalization efforts.

5. Methods

5.1. Sample, design, and procedure

The sample consisted of 82 life science doctoral programs at 12 German universities and investigated them using a document analysis. We analyzed the content of official documents describing these programs and the overall regulations for life science doctoral education under which the programs operated at their universities. We opted for document analysis as it is a non-reactive method (Schmidt, 2017) to obtain the implementation of the five aspects in the programs, and therefore more reliable than, e.g., working with potentially biased self-reports of survey participants.

Document data on the programs was collected as part of a large government-funded project on influencing factors on academic careers of graduates in the life sciences (project E-Prom). Within the general project, data collection focused on three large German regions (Bavaria, North-Rhine-Westphalia, and Saxony) and invited all universities and their life sciences doctoral graduates in these regions to participate in the project. The 82 programs which build our sample had at least one doctoral graduate who participated in the larger project. This means that the selected programs are a sample of many more life science programs in Germany. Since several cohorts of life science graduates were investigated in the project, our sample consists of 52 doctoral programs, for which data was collected and analyzed from 2014 until 2015, and 30 doctoral programs, for which data collection and analysis took place between 2016 and 2018. In the process of data collection, we searched for documents about the doctoral programs that were available online. These documents include program descriptions, regulations, and curricula that were available as text on websites, in booklets, or as PDF-documents. During the second data collection process, we also looked for revised documents of doctoral programs analyzed in the first data collection. This document was then analyzed.

To validate the findings of the document analysis, we contacted experts of the respective doctoral programs (coordinators, spokesmen, and organizers) after both rounds of searching and analysis to check whether our results were correct.

5.2. Data analysis

The documents of the 82 doctoral programs were analyzed by qualitative content analysis (Mayring, 2015) in MAXQDA Plus 2018. We developed a categorial system of a number of topics but will focus here only on (1) interdisciplinary aspects, (2) international orientation of doctoral programs, (3) courses offered as well as (4) characteristics of supervision, and (5) examination of doctoral theses. For documents in the second round, we updated the category system slightly (adding categories on current topics, e.g., courses on public outreach).

To gauge (1) the interdisciplinary aspects, we coded the doctoral degrees that doctoral candidates can earn by enrolling in the doctoral program, and the faculty hosting the program. To analyze (2) the international orientation of the investigated doctoral programs, we coded whether international doctoral candidates can enroll, the number of courses taught in English, and collaboration with universities abroad. For investigating (3) the various courses offered, both courses on academic skills and courses on key qualifications beyond academic skills (such as career and personal development) were coded. For courses on academic skills, the main categories were 'networking and collaboration', 'research management', 'research', 'publish research' (Kyvik, 2013), and 'teaching research' (Boyer, 1990). For the second document search and analysis round from 2016 to 2018, we added two subcategories of courses to the original coding scheme. Next, we coded conditions of (4) supervision, by coding for the number of supervisors supporting a doctoral candidate, the frequency of meetings between supervisors and supervisees, the availability of supervision agreements and their contents, the establishment of a thesis advisory committee (TAC), and support by further mentors. Regarding (5) the examination processes, we coded regulations on supervisors and external examiners as part of the examination committee.

To test the reliability of the document analysis on doctoral programs of the first search and analysis round, two coders independently coded 20% of the total dataset. Their analysis matched with a 91% consensus (rü = 0.91) and a Cohens-Kappa (Brennan and Prediger, 1981) of $\kappa = 0.60$—indications of good inter-rater reliability (Wirtz and Caspar, 2002). For the second search and analysis round, two coders independently analyzed 13% of the dataset of the third cohort with a consensus of 95% (rü = 0.95) and a Cohens-Kappa of $\kappa = 0.86$. These values indicate a high inter-rater reliability (Wirtz and Caspar, 2002).

To validate our analysis, we asked experts (coordinators, spokesmen, and managers of the doctoral programs) to look at a 'fact-sheet' that we created as a description of the program based on our categories and confirm or correct the results. In the first search and analysis round, we send out 'fact-sheets' to 74 experts and received 37 replied. We revised the original documents in MAXQDA accordingly.

In the second data collection and analysis round, we asked 29[2] experts to answer an online-survey regarding details of their program coinciding with the updated category system. After multiple requests, experts of 17 programs replied (59% response rate). Using 13% of the total dataset for the second search and analysis round, we compared the results of the document analysis with results of the expert evaluation and found a consensus of 95%. The document analysis results were revised according to the experts' answers.

When surveying the experts of the doctoral programs in the second round, we additionally asked open-ended questions on further topics of doctoral education in order to learn about the programs' approaches for moving improvement beyond the analysis of the documents. The answers were categorized and exemplary results are presented in the results section.

2 We excluded one doctoral program from the validation because we could not find any information on that program in the Internet at the time point of validation.

6. Results

We present our results on doctoral programs that stated that they included specific characteristics regarding (1) interdisciplinary aspects, (2) international orientation, (3) courses offered, (4) supervision, and (5) examination.

6.1. Interdisciplinary aspects

To investigate opportunities for interdisciplinary collaborations, we classified doctoral programs of our study into four categories as a function of subject area (cp. Figure 2), of the doctoral degrees, and the faculty hosting the program (medical faculty or faculty of natural science). First, we identified pure medical programs (5%) in our dataset: students of medicine or dentistry do their doctorate at a medical faculty with the aim of gaining doctoral degrees of medicine (Dr. med. or Dr. med. dent.). Second, we classified medical programs with students of other subjects (10%). Here, medical students and students of other fields (e.g., biology, psychology, and others) completed their doctorate at a medical faculty. Students of other fields in these doctoral programs gained their doctorate at a foreign faculty and can obtain special cases of doctoral degrees (cp. Figure 1). Third, there were pure natural science programs (44%)—doctoral candidates of natural sciences (e.g., biology, chemistry, and others) who completed their doctoral studies at natural science faculties. Fourth, we identified medical and natural science programs (16%) located both at medical faculties and faculties of natural science. Here, physicians and natural scientists earned medical (Dr. med., Dr. med. dent.) or natural science doctoral degrees (Dr. rer. nat.).

Our data indicate that natural scientists and physicians are working together in 26% of doctoral programs—summarizing programs for medical students and students of other subjects (10%) and medical and natural science programs (16%).

6.2. International orientation

In the investigated programs 51% indicated that international students can enroll, 45% offered courses in English, and 21% cooperated with universities from abroad. Figure 3 presents an overview of the range of doctoral degrees that can be earned in the investigated doctoral programs. Most of the programs awarded the German degree of Dr. rer. nat. (61%), while only 22% of the programs offered the international PhD; 26% of the doctoral programs did not detail which degrees doctoral candidates could acquire.

6.3. Courses offered

6.3.1. Academic skills

Table 1 presents an overview about courses offered on five academic skills.

87% (71 of 82) of doctoral programs reported offering opportunities for training 'networking and collaboration'. For this category, we coded the following courses: colloquia for doctoral candidates, program retreats, meetings, symposia and conferences of the program, summer schools and workshops for doctoral candidates as well as explicit fostering of networking activities. 85% (70 of 82) of doctoral programs offered courses on 'research'

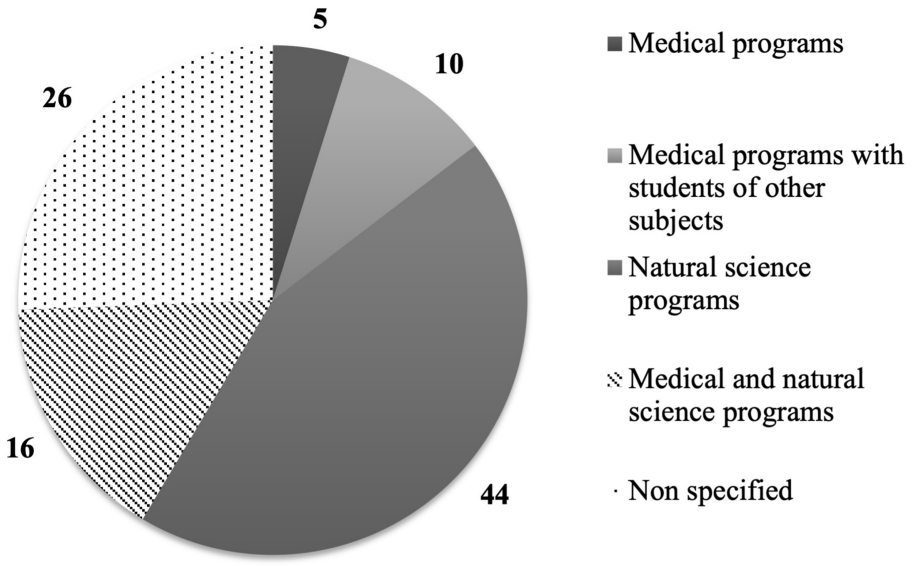

FIGURE 2
Distribution of doctoral programs as a function of subject area and faculty (as percentage).

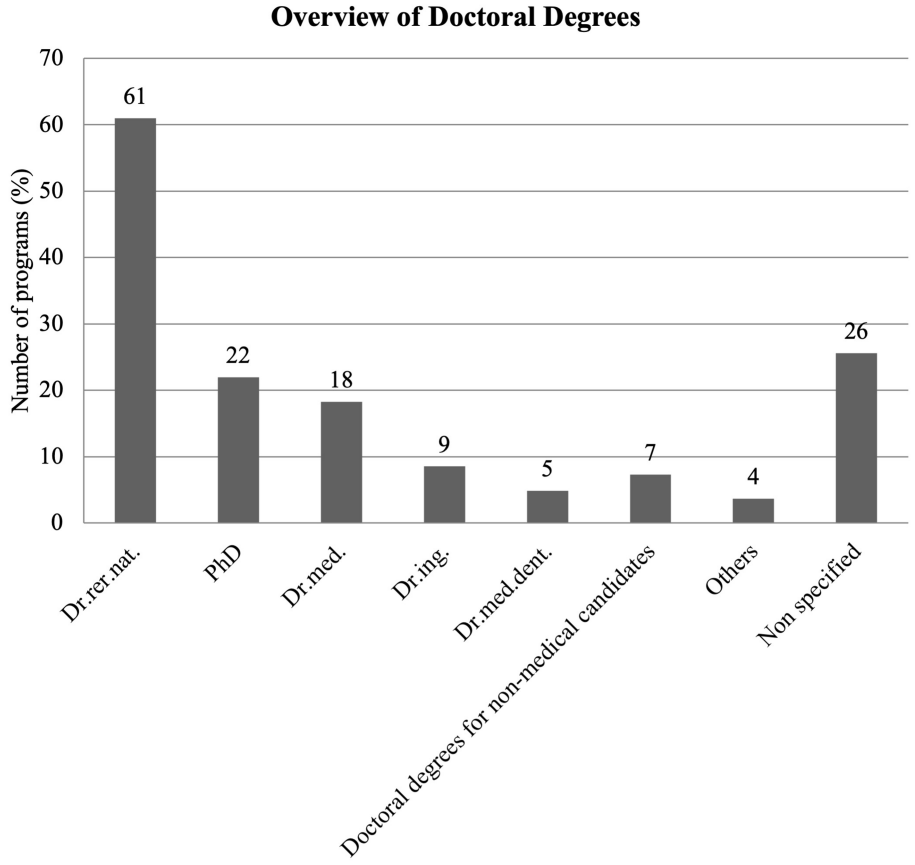

FIGURE 3
Overview of different types of doctoral degrees that can be earned in doctoral programs (as percentage). Doctoral degrees for non-medical candidates is an abbreviation for doctoral degrees that can be earned at medical faculties by non-medically qualified candidates who do not want to do a PhD.

TABLE 1 Numbers of courses on academic skills that doctoral programs of this study are providing (total numbers, number of investigated programs as reference, percentage).

Academic skill	Total number	Reference	Percentage
Networking and collaboration	71	82	87
Research	70	82	85
Publishing research	57	82	70
Research management	44	82	54
Teaching research	6	30	20

including subject-specific courses and methodological courses. 70% (57 of 82) of doctoral programs attempted to increase students' ability to 'publish research' by offering courses on writing skills, scientific communication, public outreach, open access and language. However, it should be noted that subcategories 'open access' and 'public outreach' were only analyzed in 30 programs of the second search and analysis round, with the updated category system. 13% (4 of 30) described offering courses on publishing open access and 40% (12 of 30) of programs offered courses on public outreach. 54% (44 of 82) of doctoral programs indicated courses on 'research management' (e.g., project management, good scientific practice, research funding, and legal basics, research, and ethics). Research funding was considered in 18% (15 of 82) of programs while 20% (6 of 30) of doctoral programs were found to offer courses on how to teach students about research results ('teaching ability'). The last one was analyzed in only 30 programs of the second search and analysis round.

6.3.2. Key qualifications

Key qualifications include opportunities for career development and for personal development. Overall, 52% (43 of 82) of programs included courses (28% (23 of 82)) and events (29% (24 of 82)) on career development, courses on planning academic and non-academic career paths (35% (29 of 82)), and offers on application training (22% (18 of 82)). Courses on personal development (34% (28 of 82)) were on leadership and personal management as well as on conflict management and negotiating.

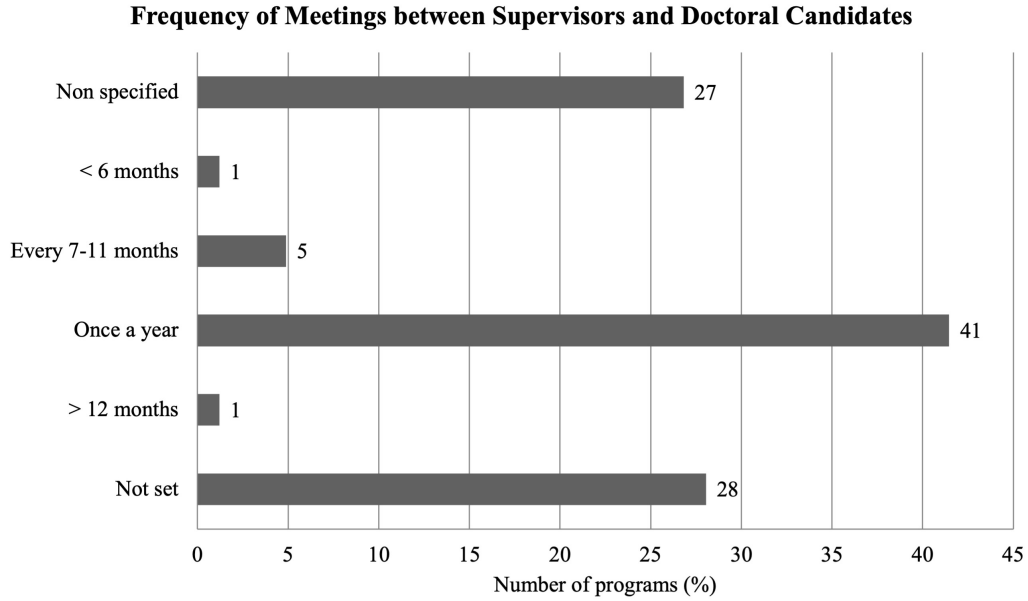

FIGURE 4
Stated frequency of meetings between supervisors and supervisees (as percentage).

6.4. Supervision

Almost half of doctoral programs supported their doctoral candidates with two (21%) or three or more supervisors (35%). 33% of them offered one supervisor per doctoral candidate. The remaining programs did not specify the number of supervisors for doctoral candidates (11%).

Figure 4 presents the stated frequency of meetings between doctoral candidates and their supervisor(s). It is notable, that most of the programs reported a frequency of once a year (41%). 55% of programs did not explicitly set a meeting frequency in their online presentation or did not discuss a meeting frequency at all (not specified).

43% of doctoral programs supported TAC supervision processes. Program experts specified the following exercises for their committees:

- Support of project planning
- Reflection and discussion about projects
- Controlling successful progress and quality of doctoral studies
- Examination of necessary qualification of doctoral candidates
- Support of networking
- Mediation in conflicts between supervisees and supervisors, mentors, colleagues, and others
- Advice about career planning and personal development

26% of doctoral programs stated that they provide additional support during doctoral studies through mentors.

39% of doctoral programs reported using a supervision agreement between doctoral candidates and their supervisors. Figure 5 provides an overview of the contents of typical supervision agreements.

The results of our analysis show that many doctoral programs demanded for regularly occurring meetings (72%), reports of supervisees to their supervisors (69%) in addition to the defined rights and obligations of both supervisees (44%) and supervisors (50%).

6.5. Examination

76% of doctoral programs indicated that supervisors examined doctoral theses. The experts provided several arguments for integrating supervisors in the examination processes: e.g. they told us, that supervisors' expertise of the subject as well as their knowledge on the progress of doctoral research are relevant factors for successful evaluation.

One doctoral program reported this interesting compromise:

> "The supervisor of the doctoral thesis submits their opinion to contextualize the thesis within the experiences that were made during the project execution. In this way, any special circumstances regarding a project situation can be taken into account, without the dissertation being graded. The thesis and the comment will be forwarded to the external reviewers, who in turn will assess the thesis independently of one another. In the process of assessment, they will take the comment in consideration at their own discretion."[3]

16% of doctoral programs stated integration of independent external examiners in evaluation processes.

3 Translated from German by the authors.

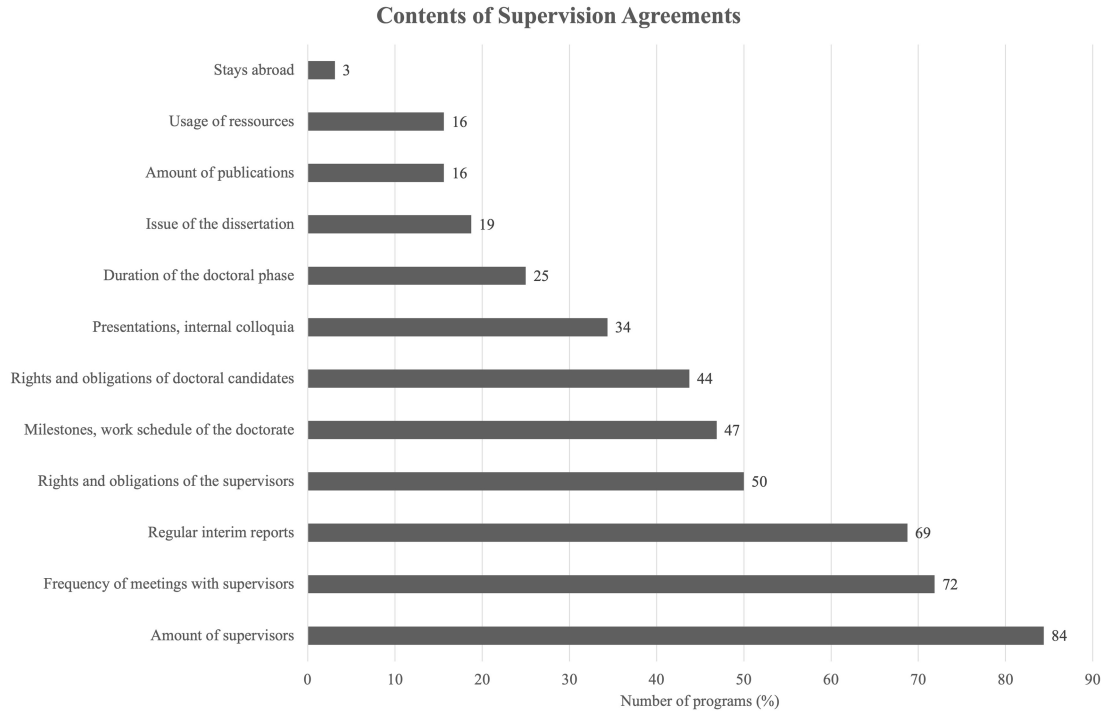

FIGURE 5
Overview of typical contents of supervision agreements (as percentage). Percentage refers to the 32 doctoral programs that reported using supervision agreements.

7. Discussion

Doctoral programs are aimed at structuring doctoral education in order to assure the high quality of doctoral studies and protect doctoral candidates during their doctorate from potential pitfalls. To understand what structure life science doctoral programs actually provide, we analyzed documents related to them. Furthermore, we investigated further details on supervision and examination of doctoral programs of the second search and analysis round with open-ended questions in surveying the experts. In the following sections we discuss results of this study separately for each aspect.

7.1. Interdisciplinary aspects

Preparation for interdisciplinary research is an important requirement for improving doctoral education (Kehm, 2006). Especially in the life sciences, interdisciplinary research is of great importance (Hellweg et al., 2017; Qin, 2017; Doody, 2020). One-third of doctoral programs in this study provided cooperation between medical researchers, natural scientists, and other researchers (cp. Figure 2) comparable to other doctoral programs in the life sciences like, e.g., the SpaceLife program researching on interdisciplinary topics of health issues during spaceflights (Hellweg et al., 2017). Hosting doctoral programs for non-medical doctoral candidates at a medical faculty (one tenth of all programs studied) comes with a risk and an opportunity: in the worst-case scenario, students of non-medical fields (e.g., biologists, psychologists, educators, and others) who had been working for their whole academic career at medical faculties, in the end could not get the clinical professoriate because of their 'inappropriate' (under)graduate studies. On the other hand, there are leading academic positions for non-physicians in academic medicine (e.g., pre-clinical professoriates). Furthermore, a major part of research activities at medical faculties is interdisciplinary and heavily involves natural and social scientists.

Graduates of doctoral programs hosted simultaneously at a medical and a natural science faculty (one sixth of the programs) did not risk a potential problem in career paths, as both medical and natural science faculties remained open to them. However, most doctoral programs in this study were in the natural sciences (more than two fifths), which probably provides career opportunities for natural scientists of various disciplines (e.g., biology, chemistry, biochemistry, engineers) who are also doing interdisciplinary research. Interdisciplinary cooperation in the life sciences will more likely proceed in the cases associated with such opportunities as preparation for collaborating research (Kyvik, 2013) and developing important skills in interdisciplinary cooperation (Manathunga et al., 2006). Such opportunities in interdisciplinary doctoral programs allow preparing doctoral candidates for interdisciplinary research which becomes more and more important—especially in the life sciences. Preparing junior researchers in interdisciplinary researching is necessary because research in cooperation with different fields may salvage various difficulties (e.g., in interdisciplinary writing, when different writing traditions and writing genres meet (Doody, 2020)). Other research fields also offer interdisciplinary programs for doctoral studies. For example, the 'Freie Universität of Berlin' in Germany offers such in political science and sociology (e.g., 'Graduate School of North American Studies' combining politics, sociology, literature, economics, culture and history) (Schneijderberg, 2018; Freie Universität Berlin. Graduate School of North American Studies

(GSNAS), 2022). These programs allow a new structure of doctoral studies centered on specific socially relevant topics in several research fields: life sciences, sociology and political science among others. This development in doctoral programs now meets suggestions on long requested advancements in doctoral education (Golde and Gallagher, 1999). In the life sciences especially, the increased shift to interdisciplinary approaches in doctoral studies considers the complexity of currently relevant problems (e.g., developing vaccines to handle the COVID-19 pandemic from medical, biological, and medical ethical perspectives).

7.2. International orientation

International orientation in doctoral education should provide competitiveness of doctoral candidates in a globalized world (e.g., Berning and Falk, 2006). For the doctoral programs in the study, only a quarter offered a PhD,[4] a half accepted international students to complete their studies, a half offered courses in English, but less than a fifth indicated cooperating with universities from abroad. Our findings suggest, that German life science doctoral programs are not having enough international outreach, which is needed to improve required competitiveness. This finding is consistent with previous findings in Germany. In Bavaria of Germany, the number of doctoral candidates completing their doctoral studies in internationally orientated doctoral programs is low (Schneijderberg, 2018). However, it should be noted that our investigation's perspective differed from that of Schneijderberg (2018). We investigated the stated structure of programs in the life sciences focusing on the international aspects but not the numbers of doctoral candidates. Whereas, Schneijderberg (2018) evaluated the number of doctoral candidates participating in internationally orientated doctoral programs. Nevertheless, the impression arises that doctoral programs in Germany are not as internationally oriented as policy demands would suggest.

7.3. Courses offered

The main benefits of doctoral programs are higher levels of formal learning in courses, and preparation of doctoral candidates for both academic and non-academic careers (e.g., Berning and Falk, 2006). Previously, most PhD holders declare that courses during doctoral training were little helpful both in- and outside academia (Kyvik and Olsen, 2012). However, our findings on five academic skills—networking and collaboration, research management, researching, publishing research and teaching research (Boyer, 1990; Kyvik, 2013)—suggest that there is still a need for extending courses offered. As recommended by Nerad (2008), more than three quarters of doctoral programs state to already train their students in 'networking and collaboration'. Our results that many life science doctoral programs implement learning opportunities on 'research' activities, 'publishing research' and 'research management' are in line with previous research on doctoral programs (Kwan, 2010; Borders et al., 2014; Buss, 2020). Our results show that, especially in the life sciences, courses in doctoral programs still focus on research-related topics like previous studies already emphasized (e.g., German life science doctoral programs focus on research methods and tools (Qin, 2017)). Many offers in research management including courses on law issues in research as well as on research funding as found in our study support previous empirical evidence for a beginning core curriculum in higher education doctoral programs (Card et al., 2016) and shows that some structuring aspects of doctoral programs are not subject-related.

Interestingly, only a few doctoral programs considered skills in publishing open access and public outreach, although these are both new important aspects of researching (Creaser, 2010). We also observed a lack of training on research funding (only one fifth of the programs offered relevant courses), which can lead to problems in future academic career paths. Without such funding, it is impossible to become an independent scholar. In Germany, many doctoral candidates are involved in teaching. Previously, structured training of teaching skills is often neither conducted in doctoral education nor by the university itself independently from doctoral studies. However, there are already efforts in Germany by many universities to offer voluntary courses to improve teaching and teaching skills of scientists regardless of scientific status [e.g., LMU. PROFiL: Professionell in der Lehre, 2023]. Nevertheless, explicitly promoting teaching competences in doctoral programs is supplementary demanded internationally (e.g., Nerad, 2008; Marx et al., 2016). Although, teaching is a central part of the scholarly profession (Boyer, 1990), only a few doctoral programs reported that they provide courses on how to teach (one fifth). This is consistent with previous international critiques on doctoral education that lack teaching skills (Wolyniak, 2003; Nerad, 2008; Jones, 2013; Schneijderberg, 2018).

Besides purely academic skills, we analyzed training in the key qualifications relevant for both academic and non-academic career paths. Courses on personal development and career development were both lacking. Only a third of doctoral programs informed doctoral candidates about career paths outside of academia, although lacking preparation for careers outside of academia had been criticized on doctoral education in Germany and internationally (e.g., Enders, 2005; Nerad, 2008; Schneijderberg, 2018). A shift from focusing solely on research during doctoral studies to integration of questions on career progress had been supposed for a long time [e.g., in natural science doctoral education in the United States (Campbell et al., 2005)]. Overall, German life science doctoral programs still implement courses on relevant up-to-date academic skills (on publishing open access and on public outreach) and key qualifications all too rarely (see section 5.3) despite career paths in the life sciences have become more diverse [e.g., careers in academia besides careers in education, industry, business, as well as in law are possible (Wolyniak, 2003)].

7.4. Supervision

Doctoral programs should improve potentially problematic supervision of doctoral candidates with an increased number of supervisors (e.g., Berning and Falk, 2006). Previous studies provided

4 Doctoral graduation with a PhD as doctoral degree is an advantage in the international scientific context because it is internationally recognized. Though, researchers from abroad (e.g., in the United States) can assess the scientific effort made by a life science doctoral graduate with a PhD better than the scientific effort of a life scientist with a German degree (e.g., Dr. rer. nat.).

evidence, that group supervision and peer learning may enrich learning during the doctorate as well as identity development processes (Fenge, 2012). However, one third of doctoral programs stated there was only one supervisor. Our findings match results of a previous study at Bavarian universities showing that mostly one supervisor will guide each doctoral candidate—as is the case in the traditional master-apprentice-model and doctoral programs (Schneijderberg, 2018). In life sciences, compared with other subjects, professors do not usually supervise doctoral students by themselves; e.g. only one third of medical professors indicate supervising their doctoral candidates solely by themselves (Berning and Falk, 2006). Consequently, our findings are similar to those of previous studies in Germany. However, it is important to note that the results of a survey of professors presented by Berning and Falk (2006) did not solely refer to doctoral studies in doctoral programs, but included doctoral studies in the traditional master-apprentice model as well. It is noteworthy that doctoral programs in the life sciences seem not to provide more significant formal structure in supervision through an increased number of supervisors than the master-apprentice-model, despite the policy demands for this.

Regularly meetings between supervisors and doctoral candidates should improve doctoral education (GSC, 2011). However, half of doctoral programs in this study did not define the frequency of meetings. When regularly meetings were specified, most of the programs stated only one per year, which is too rare for discussing relevant aspects of doctoral studies (e.g., defining a topic, preparing and conducting data collection, analyzing data, writing scientific articles). Our findings are not in agreement with findings on meeting frequencies in Germany independent from the form of doctoral studies when most doctoral candidates meet their supervisors several times a semester (BuWiN, 2021). In Germany, professors will indicate their agreement to supervise their doctoral candidates in frequent one-to-one meetings, colloquia or other forms of advisory offers (Berning and Falk, 2006; Schneijderberg, 2018). Here, our results seem to be field-specific. Additionally, it is conspicuous that doctoral programs do not provide extensive formal structures for frequent meetings with supervisors. We assume that the knowledge about optimal supervision of doctoral candidates via regular meetings has already passed into everyday practice of supervising doctoral candidates as some experts of the investigated doctoral programs confirmed. One expert stated that supervision still depends on the goodwill and motivation of the supervisors while increasing transparency in supervision through formalized procedures foster awareness for more accurate planning of doctoral studies in most supervisors. If this is so, the need for doctoral programs to include formal regular meetings would not to be urgent. It should be noted that there are still cases where doctoral students are not able to have such regular one-on-one meetings or the like (Berning and Falk, 2006; Schneijderberg, 2018). Therefore, despite apparent general knowledge about the relevance of regular meetings with doctoral students, they should be formally specified, so that each doctoral student is well guided in the process of their doctoral studies.

The program experts expected the committees (TAC) to support doctoral education through discussions with the candidates, sustaining a form of quality control for doctorates just as recommended (GSC, 2011). However, not even half of the programs provided a TAC. This result does not match exactly previous results. Qin (2017) found that the investigated doctoral programs introduced TAC for controlling quality in doctoral studies and enables supervision of doctoral candidates through multiple supervisors from different fields. With TAC, interdisciplinarity of life science research had been facilitated (Qin, 2017). Differences in the results of Qin's and our study may be caused by different methodological approaches. While Qin's results are based on qualitative research with interviews and case studies of two German doctoral programs in the life sciences, we tried to get an overview about many life science doctoral programs in Germany investigating the regulations of 82 programs. In our study, some doctoral programs report to support their supervision through TAC, but some programs do not. Thus, Qin could have randomly selected two programs that offer TAC. Although, mentors are meant to support doctoral candidates more informally, only one third of programs provided mentors. This result could reflect the desire of professors to maintain sole responsibility of supervision (Berning and Falk, 2006). Another reason for the small number of doctoral programs reporting to integrate mentors in supervision may be parallel offers of the university in general as mentioned by some experts of the present study. Thus, doctoral students would have the opportunity to be supported by mentors, even if the programs themselves do not explicitly offer mentors. Otherwise, doctoral programs did not include mentors in supervision processes due to potential conflicts for doctoral candidates when supervisors and mentors have contrary types of supervision and opposing suggestions in consultations (e.g., Hauss et al., 2012; Olmes-López and Sunderland, 2017). In general, however, there are efforts of universities in Germany to divide responsibilities of supervision to several supervising persons (professors, mentors) (Schneijderberg, 2018).

To avoid potential exploitation of doctoral candidates, agreements can be made to formalize supervision. Clearly stated requirements in doctoral education foster high-quality dissertations (Lovitts, 2007). In our study, only one third of life science doctoral programs used such agreements. Our results are in contrast to previous research, which showed a general trend to more formalized doctoral education through supervision agreements in Germany (Schneijderberg, 2018; BuWiN, 2021). Thus, many life science doctoral programs still lack explicit formalization of supervision, confirming previous findings in the life sciences from the analysis of regulations on education in doctoral programs (Lachmann et al., 2020). Independently from the research field though, a survey on doctoral candidates in Germany showed that those in doctoral programs had a supervision agreement more often than those in master-apprentice-models (BuWiN, 2021). For research field-specific results, especially in the life sciences, many doctoral candidates indicated having a supervision agreement (BuWiN, 2021). These results, however, need not to be viewed as counter to our findings because the level of analysis differs; the BuWiN (2021) results refer to self-reporting of doctoral candidates, whereas we analyzed the regulations of doctoral programs. Additionally, the results of BuWiN (2021) did not specify the number of doctoral candidates in doctoral programs with supervision agreements. Therefore, the results of this study add new insights to the specific field of life science doctoral programs' regulation design.

7.5. Examination

Instating supervisors as examiners has been questioned for potential conflicts of interest, because they would be evaluating their own mentoring (e.g., GSC, 2011). Nevertheless, most of

doctoral programs engage supervisors as examiners (almost four fifths). Reasons put forward to justify this decision include supervisors' being experts in the specific field of the doctoral thesis and knowing best the progress and hurdles of the studies. Besides simple solutions for this dispute (external examiners could use the supervisors' assessment on study progress at their own discretion) further research should develop and evaluate more solutions for improving transparency and consistency of examination. As commonly done in the United States (Nerad, 2008), external examiners are part of examination committees in some doctoral programs in our German sample. Still, life science doctoral programs rarely include innovative examination approaches. Previous studies have already hinted some efforts of universities in structuring more objective approaches of examination in other research fields; during the examination of sociological doctoral theses at a German university, co-authors of articles embedded in the doctoral thesis are not allowed to grade these articles when they evaluate the doctoral thesis as part of the examination committee (Schneijderberg, 2018). Here, examination activities of examiners are limited due to their contribution during the process of doctoral studies. Investigations on examination approaches in the life sciences—especially in doctoral programs—are lacking. This study has added new insights on examination processes in life science doctoral programs that may be interesting for other research fields.

The doctoral programs differed widely in the extent to which the stated demands for an improved doctoral education had been implemented. Although German life science doctoral programs currently contain some of the suggestions, many improvements need to be instituted, which has some practical implications for doctoral program coordinators.

8. Practical implications

Major changes in life science doctoral programs are needed to fulfil the requirements for improving doctoral education. Since life science programs are long established and even life science programs have some remaining points for improvement, it can be concluded that implications of this study also apply to programs in other disciplines. Additionally, the improvement of doctoral education through doctoral programs is an internationally discussed issue. Therefore, implications of this German study provide some indications for other countries, even if they have their own main difficulties in doctoral education (Nerad and Heggelund, 2008).

Doctoral programs should include cooperation with other disciplines fostering relevant academic skills such as networking and international collaboration (e.g., Enders, 2005; Manathunga et al., 2006). In German programs potential problematic career paths of doctoral graduates in foreign faculties should be avoided (cp. section 6.1). When students with different basic studies enroll in interdisciplinary doctoral programs, respective associated faculties could host them.

In the international context, for improving internationality and competitiveness (Berning and Falk, 2006), program coordinators should increase the number of courses in English and try to facilitate the enrollment of foreign doctoral students. Lastly, more programs, especially in Germany, should provide the opportunity of earning a PhD.

All education in these programs should stay up to date internationally. Therefore, course offers as formal learning opportunities should include training in several relevant realms—e.g. in teaching ability, publishing open access, and public outreach (Nerad, 2008; Creaser, 2010).

Skopek et al. (2020) have emphasized the importance of structuring doctoral studies through deadlines. By considering the interruption of supervision by determined meetings and the full schedule of both supervisors and doctoral candidates, coordinators should set a minimum of meetings, while doctoral candidates and supervisors should agree on an individual frequency of meetings.

Program coordinators should also consider the debates about supervisors' examining doctoral theses (e.g., GSC, 2011). Our findings suggest that external examiners could consider supervisors' reports on study progress and that supervisors do not grade doctoral theses. Having an external reviewer as part of examination committees, as practiced in the United States (Nerad, 2008), could guarantee a higher level of objectivity in examination. This implication does not apply to the United States because this approach is currently and widely practiced there.

9. Limitations and future research direction

This study on life science doctoral programs in Germany is based on a document analysis of available information on the internet—improved by additional survey data from experts of investigated doctoral programs as recommended by Schmidt (2017). Typically, information from online documents is limited by their function of informing interested students about such programs (Schmidt, 2017). Thus, document analysis cannot finally clarify whether certain topics are not ruled or defined in the programs or whether these topics are only not addressed in the documents found, but are indeed specified in the implementation of the programs in reality. However, document analysis enables focusing on perspectives other than those of doctoral candidates. Previous studies on doctoral education in doctoral programs has so far mostly examined survey data (e.g., Ambrasat and Tesch, 2017; Barnett et al., 2017; BuWiN, 2021). Therefore, document analysis adds a new prospect [comparably to the study conducted by Kwan (2010)] although information of the documents is limited. Document analysis does not consider individual experiences of doctoral students. Therefore, it can only give an overview of formal and theoretical conditions, but not represent real experiences of doctoral students. Alternatively, the doctoral programs could also have been analyzed using a survey from doctoral students for capturing their experiences or a survey from administrative staff of the programs for capturing the regulations from another perspective. Further research could evaluate the formally implemented elements of doctoral programs presented here through the perspectives of doctoral candidates and administrative staff to get an overall view of doctoral education's conditions.

Since this study was based on life science doctoral programs in Germany, generalizations of conclusions are somewhat limited. Experiences in and conditions of doctoral education are still subject-related (Qin, 2017)—working on a doctoral thesis in sociology at an American university differ from experiences during a biological doctorate at a German university despite doctoral

programs attempt to equalize doctoral education's conditions through standardized and formalized conditions for transparency and improved quality (Ambrasat and Tesch, 2017). It should be noted that practical implications of our study cannot simply be extrapolated to other countries for there is empirical evidence that, e.g., while European and U.S. programs do have significant overlap, there are also some differences in structure, mentoring, and assessment (Barnett et al., 2017). Further studies on doctoral programs in other fields (e.g., in humanities) and other countries (e.g., the United States) would be beneficial for future comparison and discussion of our findings. Lastly, there are differences within doctoral programs due to their organizational structure—already described in other studies (e.g., Korff and Roman, 2013). That was not focused in this study here. We rather focused on the general structure and formalization of doctoral programs in the life sciences considering the five aspects.

10. Conclusion

Life science doctoral programs in Germany differ in the structuring of doctoral education. Although, they implement some activities required for educational improvement including interdisciplinary cooperation, international orientation, broad courses offered, structured supervision, and alternative examination approaches, shortfalls remain. Doctoral programs in Germany and internationally should be further developed and evaluated.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics committee of the Medical Faculty of LMU Munich (Ethics approval numbers: 368–14 and 19–332). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JM further developed the coding manual, developed the extert's survey, collected the data of the survey, processed the data for publication (expert's survey and document analysis), analyzed the data, planned the manuscript, and wrote the manuscript in a leading position. WB, MF, BN, and JE developed the study design, contributed to the development of the original coding manual, supported the data collection and analysis, and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Al Makhamreh, M., and Stockley, D. (2020). Mentorship and well-being: examining doctoral students' lived experiences in doctoral supervision context. *Int. J. Mentor. Coach. Educ.* 9, 1–20. doi: 10.1108/IJMCE-02-2019-0013

Ambrasat, J., and Tesch, J. (2017). Structured diversity: the changing landscape of doctoral training in Germany after the introduction of structured doctoral programs. *Res. Eval.* 26, 292–301. doi: 10.1093/reseval/rvx024

Ammon, U. (2006). Language planning for international scientific communication: an overview of questions and potential solutions. *Curr. Issues Lang. Plan.* 7, 1–30. doi: 10.2167/cilp088.0

Barnett, J. V., Harris, R. A., and Mulvany, M. J. (2017). A comparison of best practices for doctoral training in Europe and North America. *REBS Open Bio.* 7, 1444–1452. doi: 10.1002/2211-5463.12305

Bekova, S. K., and Terentev, E. A. (2020). Doctoral education: international experience and opportunities for its implementation in Russia. *Higher Educ. Russia* 29, 51–64. doi: 10.31992/0869-3617-2020-6-51-64

Berning, E., and Falk, S. (2006). *Promovieren an den Universitäten in Bayern: Praxis, Modelle, Perspektiven [doctorates at universities in Bavaria: Practice, models, perspectives]. Bd. 72.* München: Bayerisches Staatsinstitut für Hochschulforschung und Hochschulplanung.

Bernstein, B. L., Evans, B., Fyffe, J., Halai, N., Hall, F. L., Marsh, H., et al. (2014). "The continuing evolution of the research doctorate" in *Globalization and its impacts on the quality of PhD education: forces and forms in doctoral education worldwide*. eds. M. Nerad and B. Evans (Rotterdam: Sense Publishers), 5–30.

Borders, L. D., Wester, K. L., Fickling, M. J., and Adamson, N. A. (2014). Research training in CACREP-accredited doctoral programs. *Couns. Educ. Superv.* 53, 145–160. doi: 10.1002/j.1556-6978.2014.00054.x

Boyer, E. L. (1990). *Scholarship reconsidered: priorities of the professoriate. The carnegie foundation for the advancement of teaching*. New York: John Wiley and Sons.

Braun, S., and Hadwiger, K. (2011). Knowledge transfer from research to industry (SMEs): an example from the food sector. *Trends Food Sci. Technol.* 22, S90–S96. doi: 10.1016/j.tifs.2011.03.005

Brennan, R. L., and Prediger, D. J. (1981). Coefficient kappa: some uses, misuses, and alternatives. *Educ. Psychol. Meas.* 41, 687–699. doi: 10.1177/001316448104100307

Buss, R. R. (2020). Exploring the development of students' identities as educational leaders and educational researchers in a professional practice doctoral program. *Studies Higher Educ.* 47, 1069–1083. doi: 10.1080/03075079.2020.1836484

BuWiN (2017). *Bundesbericht Wissenschaftlicher Nachwuchs 2017: Statistische Daten und Forschungsbefunde zu Promovierenden und Promovierten in Deutschland [National report on junior researchers 2017: Statistical data and research findings on doctoral candidates and graduates in Germany]*. Bielefeld: Bertelsmann.

BuWiN (2021). *Bundesbericht Wissenschaftlicher Nachwuchs 2021: Statistische Daten und Forschungsbefunde zu Promovierenden und Promovierten in Deutschland [national report on junior researchers 2021: statistical data and research findings on doctoral candidates and graduates in Germany]*. Bielefeld: wbv Publikation.

Campbell, S. P., Fuller, A. K., and Patrick, D. A. G. (2005). Looking beyond research in doctoral education. *Front. Ecol. Environ.* 3, 153–160. doi: 10.1890/1540-9295(2005)003[0153:LBRIDE]2.0.CO;2

Card, K., Chambers, C. R., and Freeman, S. Jr. (2016). Is there a core curriculum across higher education doc-toral programs? *Int. J. Dr. Stud.* 11, 127–146. doi: 10.28945/3409

Creaser, C. (2010). Open access to research outputs—institutional policies and researchers' views: results from two complementary surveys. *New Rev. Acad. Librariansh.* 16, 4–25. doi: 10.1080/13614530903162854

Cutri, J. (2019). "The third space: fostering intercultural communicative competence within doctoral education," In *Wellbeing in doctoral education. Insights and guidance from the student experience*, ed. L. Pretorius, L. Macaulay and CauuxB. Cahusac de (Singapore: Springer), 265–279.

Doody, S. (2020). *Interdisciplinary writing should be simple, but it isn't: a study of meta-genres in interdisciplinary life sciences doctoral programs*. [Dissertation]. [Montreal] McGill University.

Ehrenberg, R. G., Zuckerman, H., Groen, J. A., and Brucker, S. M. (2010). *Educating scholars. Doctoral education in the humanities*. Princeton: Princeton University Press.

Enders, J. (2005). Brauchen die Universitäten in Deutschland ein neues Paradigma der Nachwuchsausbildung? [Do universities in Germany need a new paradigm of junior scholars' education]. *Beiträge zur Hochschulforschung* 27, 34–47.

Fenge, L.-A. (2012). Enhancing the doctoral journey: the role of group supervision in supporting collaborative learning and creativity. *Stud. High. Educ.* 37, 401–414. doi: 10.1080/03075079.2010.520697

Freie Universität Berlin. Graduate School of North American Studies (GSNAS). (2022). Available at: https://www.jfki.fu-berlin.de/en/graduateschool/docs_postdocs/index.html (Accessed March 27, 2022).

Gardner, S. K. (2010). Contrasting the socialization experiences of doctoral students in high- and low-completing departments. A qualitative analysis of disciplinary contexts at one institution. *J. High. Educ.* 81, 61–81. doi: 10.1080/00221546.2010.11778970

Germain-Alamartine, E., Ahoba-Sam, R., Moghadam-Saman, S., and Evers, G. (2021). Doctoral graduates' transition to industry: networks as a mechanism? Cases from Norway, Sweden and the UK. *Stud. High. Educ.* 46, 2680–2695. doi: 10.1080/03075079.2020.1754783

Golde, C. M., and Gallagher, H. A. (1999). The challenges of conducting interdisciplinary research in traditional doctoral programs. *Ecosystems* 2, 281–285. doi: 10.1007/s100219900076

GSHC (2002). *Wissenschaftsrat empfiehlt flächendeckende Einführung von Promotionskollegs [German Science and Humanities Council recommends nationwide introduction of doctoral colleges]*. Berlin.

GSC (2011). Anforderungen an die Qualitätssicherung der Promotion: positionspapier [Requirements for quality control of doctorates: position paper]. Available at: https://www.wissenschaftsrat.de/download/archiv/1704-11.html

Hauss, K., Kaulisch, M., Zinnbauer, M., Tesch, J., Fräßdorf, A., Hinze, S., et al., (2012). *Promovierende im Profil: Wege, Strukturen und Rahmenbedingungen von Promotionen in Deutschland [doctoral students in profile: pathways, structures and framework conditions of doctorates in Germany]*. iFQ-Working Paper, *13*. Berlin: iFQ - Institut für Forschungsinformation und Qualitätssicherung.

Hellweg, C. E., Gerzer, R., and Reitz, G. (2017). A new chapter in doctoral candidate training: the Helmholtz space life sciences research school (SpaceLife). *Acta Astronaut.* 68, 1620–1627. doi: 10.1016/j.actaastro.2010.03.014

Hornbostel, S., and Simon, D. (2010). *Strukturwandel des deutschen Forschungssystems: Herausforderungen, Problemlagen und Chancen [structural change of the German research system: challenges, problems, and opportunities]*. Hrsg.: Hans-Böckler-Stiftung. Arbeitspapier 206. Düsseldorf.

HRK (2012). Zur Qualitätssicherung in Promotionsverfahren: Empfehlungen des Präsidiums der HRK an die promotionsberechtigten Hochschulen [On quality control during doctorates: recommendations of the HRK Presidium to universities authorized to award doctorates]. Available at: https://www.hrk.de/uploads/tx_szconvention/Empfehlung_Qualitaetssicherung_Promotion_23042012.pdf

Jacob, M., and Meek, L. (2013). Scientific mobility and international research networks. Trends and policy tools for promoting research excellence and capacity building. *Stud. High. Educ.* 38, 331–344. doi: 10.1080/03075079.2013.773789

Jones, W. (2013). Issues in doctoral studies. Forty years of journal discussion: where have we been and where are we going? *Int. J. Dr. Stud.* 8, 083–104. doi: 10.28945/1871

Kehm, B. M. (2006). "Doctoral education in Europe and North America. A comparative analysis" in *Wenn-Gren international series, Vol. 83: the formative years of scholars* ed. Teichler, U. (London: Portland Press), 67–78.

Kidman, J., Manathunga, C., and Cornforth, S. (2017). Intercultural PhD supervision: exploring the hidden curriculum in a social science faculty doctoral programme. *Higher Educ. Res. Dev.* 36, 1208–1221. doi: 10.1080/07294360.2017.1303457

Korff, S., and Roman, N. (eds) (2013). *Promovieren nach plan? Chancengleichheit in der strukturierten Promotionsförderung [doctorate by plan? Equal opportunities in structured doctoral funding]*. New York, NY: Springer VS.

Kwan, B. S. C. (2010). An investigation of instruction in research publishing offered in doctoral programs: the Hong Kong case. *High. Educ.* 59, 55–68. doi: 10.1007/s10734-009-9233-x

Kyvik, S. (2013). The academic researcher role: enhancing expectations and improved performance. *High. Educ.* 65, 525–538. doi: 10.1007/s10734-012-9561-0

Kyvik, S., and Olsen, T. B. (2012). The relevance of doctoral training in different labour markets. *J. Educ. Work.* 25, 205–224. doi: 10.1080/13639080.2010.538376

Lachmann, D., Martius, T., Eberle, J., Landmann, M., von Kotzebue, L., Neuhaus, B. J., et al., (2020). Regulations and practices of structured doctoral education in the life sciences in Germany. *PLoS ONE*, 15, e0233415. doi: 10.1371/journal.pone.0233415

LMU (2016). Promotionsordnung der Ludwig-Maximilians-Universität München für die Fakultät für Biologie vom 27. November 1991. In der Fassung der 4. Änderungssatzung vom 29.09.2016 [Doctoral regulations of the Ludwig-Maximilians-University of Munich for the faculty of biology dated November 27, 1991. As changed by the 4th amendment statute dated September 29, 2016.]. Available at: https://www.bio.lmu.de/downloads/promo_ordnung_2016.pdf (Accessed March 02, 2023).

LMU. PROFiL: Professionell in der Lehre. (2023) [Professional in teaching]. Available at: https://www.profil.uni-muenchen.de/index.html (Accessed February 28, 2023).

Lovitts, B. E. (2007). *Making the implicit explicit. Creating performance expectations for the dissertation*. Sterling: Stylus.

Maloshonok, N., and Terentev, E. (2019). National barriers to the completion of doctoral programs at Russian universities. *High. Educ.* 77, 195–211. doi: 10.1007/s10734-018-0267-9

Manathunga, C., Lant, P., and Mellick, G. (2006). Imagining an interdisciplinary doctoral pedagogy. *Teach. High. Educ.* 11, 365–379. doi: 10.1080/13562510600680954

Martius, T., Lachmann, D., Landmann, M., and Herzig, S. (2014). Structure vs. freedom – or how to acquire relevant competencies to gain your doctorate. Oral presentation and paper submission at the conference of the European Association of Institutional Research (EAIR) 2014 in Essen.

Marx, R. D., Garcia, J. E., Butterfield, D. A., Kappen, J. A., and Baldwin, T. T. (2016). Isn't it time we did something about the lack of teaching preparation in business doctoral programs? *J. Manag. Educ.* 40, 489–515. doi: 10.1177/1052562915616430

Mayring, P. (2015). *Qualitative Inhaltsanalyse. Grundlagen und Techniken [qualitative content analysis. Basics and techniques]*. (*12th* Edn.). Weinheim: Beltz.

McWilliam, E., Taylor, P., Thomson, P., Green, B., Maxwell, T., Wildy, H., et al., (2002). *Research training in doctoral programs: what can be learned from professional doctorates? Commonwealth Dept of Education*, Science & Training, Australia, Canberra.

Meneghini, R., and Packer, A. L. (2007). Is there science beyond English? Initiatives to increase the quality and visibility of non-English publications might help to break down language barriers in scientific communication. *EMBO Rep.* 8, 112–116. doi: 10.1038/sj.embor.7400906

Nerad, M. (2008). ""Unites states of America," in toward a global PhD?" in *Forces and forms in doctoral education worldwide*. eds. M. Nerad and M. Heggelund (Seattle: University of Washington Press), 278–299.

Nerad, M., and Heggelund, M., ed. (2008). *Toward a global PhD? Forces and forms in doctoral education worldwide*. Seattle: University of Washington Press.

Olmes-López, P., and Sunderland, J. (2017). Doctoral supervisors' and supervisees' responses to co-supervision. *J. Furth. High. Educ.* 41, 727–740. doi: 10.1080/0309877X.2016.1177166

Plasa, T. N. (2014). Studienbedingungen und Berufseinstieg in der Biologie [study conditions and career entry in biology]. *Biologie in unserer Zeit* 44, 364–366. doi: 10.1002/biuz.201490091

Qin, L. (2017). Structuralization of doctoral education in Germany: an interdisciplinary comparison. *Eur. J. Higher Educ.* 7, 261–275. doi: 10.1080/21568235.2017.1290876

Schmidt, W. (2017). "Dokumentenanalyse in der Organisationsforschung [document analysis in organizational research]" in *Handbuch Empirische Organisationsforschung*. eds. S. Liebig, W. Matiaske and S. Rosenbohm (Wiesbaden: Springer Fachmedien), 443–466.

Schneijderberg, C. (2018). *Promovieren in den Sozialwissenschaften. Eine sozialisationstheoretische Erschließung des Forschungsfeldes promotion. [doctorates in the social sciences. A socialization-theoretical exploration of the field of doctorates]*. Wiesbaden: Springer.

Skopek, J., Triventi, M., and Blossfeld, H.-P. (2020). How do institutional factors shape PhD completion rates? An analysis of long-term changes in a European doctoral program. *Stud. Higher Educ.* 47, 318–337. doi: 10.1080/03075079.2020.1744125

Sursock, A., and Smidt, H. (2010). *Trends 2010: a decade of change in European higher education*. European University Association: Brussels.

The European Higher Education Area. (1999). *Joint declaration of the ministers responsible for higher education. Convened in Bologna on the 19th of June 1999.* Available at: http://www.aic.lv/ace/ace_disk/Bologna/maindoc/bologna_declaration.pdf

Vanstone, M., Hibbert, K., Kinsella, A., McKenzie, P. J., Pittman, A., and Lingard, L. (2013). Interdisciplinary doctoral research supervision: a scoping review. *FIMS Publications.* 43, 42–67. doi: 10.47678/cjhe.v43i2.2403

Walker, G. (2008). Doctoral education in the United States of America. *High. Educ. Eur.* 33, 35–43. doi: 10.1080/03797720802228142

Ward, P., Parker, M., Sutherland, S., and Sinclair, C. (2011). A critical examination of the curriculum of physical education teacher education doctoral programs. *J. Teach. Phys. Educ.* 30, 145–156. doi: 10.1123/jtpe.30.2.145

Wirtz, M., and Caspar, F. (2002). *Beurteilerübereinstimmung und Beurteilerreliabilität. Methoden zur Bestimmung und Verbesserung der Zuverlässigkeit von Einschätzungen mittels Kategoriensystemen und Ratingskalen [Consensus and interrater reliability. Methods for determining and improving reliability of assessments using category systems and rating scales]*. Göttingen: Hogrefe-Verlag.

Wolyniak, M. J. (2003). Balancing teaching and research experiences in doctoral training programs: lessons for the future educator. *Cell Biol. Educ.* 2, 228–232. doi: 10.1187/cbe.03-03-0016

10.3389/feduc.2023.930283

Appendix

In the following table, we give an overview of the abbreviations and Latin names or meanings of German doctoral degrees.

TABLE 2A Overview of selected abbreviations and Latin names of German doctoral degrees in the life sciences.

Abbreviation	Latin name/meaning
Dr. med.	Medicinae
Dr. med. dent.	Medicinae dentariae
Dr. rer. nat.	Rerum naturalium
Dr. rer. biol. hum.	Rerum biologiae humanae
Dr. rer. medic.	Rerum medicarum
Dr. nat. med.	Naturalium medicinae
Dr. ing.	Engineering
Dr. agr.	Agriculturae
Dr. phil.	Philosophiae