Universitetskanslersämbetets utbildningsutvärderingar

Självvärdering forskarutbildning

Lärosäte	Örebro Universitet
Forskarutbildningsämne	Kemi
Licentiatexamen	Ja
Doktorsexamen	Ja

Background information

Research and education within chemistry come under the School of Science and Technology within the Faculty of Business, Science and Engineering. The school's research activities are organised around multidisciplinary research teams and projects, instead of being divided by subject only. In practice, chemistry research at Örebro University (ORU) is a central part of two of the university's strong research environments, namely, the Man-Technology-Environment (MTM) research centre and the Life Science Centre. Research is carried out in multidisciplinary groups and is offered with the following specialisations:

- analytical chemistry/environmental chemistry
- biochemistry
- inorganic chemistry/bio-geochemistry

The doctoral programme in chemistry at ORU was established in 2000 and was initially thematically-oriented within a multidisciplinary research school. The Division of Chemistry has a committee of supervisors and a Head of subject, who together with the head of school are responsible for the doctoral programme.

Within the subject, the doctoral programme is offered with a specialisation in life science, in collaboration with the biology department, as well as with a specialisation in environmental science. It should be noted that the areas in focus on the doctoral programme reflect the areas covered at the undergraduate level, i.e. analytical, organic/inorganic and environmental chemistry. Thus, there are some sub-disciplines that are not offered at ORU, such as physical chemistry, radiochemistry or polymer chemistry. This may have some impact on the doctoral studies, as some of the subfields not covered by the university might be relevant as supportive parts of the research.

Under the general syllabus (ASP) in chemistry, doctoral students should have 7.5 credits generated from compulsory courses, 22.5-52.5 credits from elective courses, and 180-210 credits from the thesis. In addition, the two additional chemistry specializations, in life science

and environmental science, include 15-15.5 credits worth of compulsory courses, and 15-45 credits from elective courses. Due to the broad range of research topics in chemistry, the proportion of elective courses is relatively high, in order to guarantee that each student can select courses that support their individual projects in the best possible manner. The selection of elective courses for individual doctoral students is discussed in the committee of supervisors. Passed courses are registered in Ladok and entered in the doctoral student's ISP. The ISP is also used to plan the doctoral student's course work. The intended learning outcomes for the award of the degree, also known as the qualitative targets, are provided in the general syllabus (ASP).

Composition of the doctoral student group

Currently, there are 13 doctoral students on the doctoral programme (8 women and 5 men, median age 33). Three come from abroad and four are externally employed doctoral students. When recruiting new doctoral students, all positions are advertised externally on the university's website and disseminated via other channels, such as international mailing lists within MTM's network and the research groups' other professional networks, such as SWACCS and Norman networks (see description of these below). For admission to the doctoral programme, applicants are required to meet general and specific entry requirements, specified by the faculty board. The general requirements are provided in the Higher Education Ordinance (Högskoleförordningen) and the university's selection criteria are laid down in annex 2 to the general syllabus for chemistry. If applicants have equal qualifications, preference will be given to applicants of the sex that is underrepresented among the doctoral students in the subject.

Conditions

Staff

Supervisors are selected so that they have the scholarly expertise required, experience of doctoral student supervision, and sufficient teaching expertise, as specified in the quality assurance procedures of the university.[1,2] According to university guidelines, a docentship is required for principal supervisors. Supervisors in chemistry at ORU have broad competence within the subject. Their areas of expertise include environmental and analytical chemistry, occupational chemistry, metabolomics, biology, systems medicine/bioinformatics and industrial chemistry – reflecting the multidisciplinary nature of the areas of our doctoral research.

Each doctoral student has at least two supervisors which are normally appointed at the time of admission.[2] For externally employed students, one co-supervisor is appointed from the

[1] https://www.oru.se/globalassets/oru-en/education/research-education/regelhandbok-for-utbildning-pa-forskarniva_en.pdf

[2] https://inforum.oru.se/globalassets/inforum-sv/centrala-dokument/styrdokument/utbildning_forskning_samverkan/utbildning_grund_avancerad_forskar/handledning-inom-utbildning-pa-forskarniva.pdf (in Swedish)

company in question. The decision must be preceded by consultation with the Head of subject and the committee of supervisors. A supervisor should not normally be the principal supervisor of more than five doctoral students. Exceptions can be made after consultation with the dean. The head of school appoints supervisors and also makes decisions about replacing supervisors. The supervisors can be replaced upon request of the doctoral student.

The chemistry division has currently three full-time professors, three guest professors (5-50% of full-time working hours), seven senior lecturers, one adjunct lecturer, two postdoc researchers and three researchers with a PhD. Currently, seven of them have a docentship. Some of the professors have also management functions within ORU. On an annual basis, the faculty provides an updated overview of the number of professors in each subject area of the faculty. In addition, there are several affiliated researchers outside the university that are/can be assistant supervisors. Moreover, the composition of the personnel is international, both at the senior level and at the postdoc level.

Composition of the group of supervisors

The chemistry division currently has 13 doctoral students, each of whom has one principal supervisor and 2-3 assistant supervisors. Currently, the number of supervisors is 19, and of those, 11 are staff members at ORU, 5 have their main appointment elsewhere, of those 4 have an affiliation at the ORU and 2 assistant supervisors are industry-based. Of the supervisors, 54% are women and 46% are men. All principal supervisors and the majority of the assistant supervisors have the qualifications required for appointment as docent.

All the principal supervisors have funding (external and/or from the faculty) for their own research and supervision. Many of the research projects are done in collaboration with industry and/or the public sector. Faculty funding is provided in the form of professor funds and senior lecturer support. The latter can be applied for from the faculty and is evaluated every one or two years. These funds guarantee time for research and supervision equivalent to at least 50% of full working hours for lecturers and up to 60% for the professors. In addition, most supervisors, excluding the external ones, participate in teaching in first- and second-cycle courses (min. 20% of full-time working hours required by the university). The faculty also gives financial support for further development of pedagogical projects and the teaching skills. Thereby, the supervisors' teaching skills are maintained and developed. In addition to the current supervisors, there are several staff with a doctoral degree (8 senior lectures/senior researchers, 3 postdoc researchers, 3 researchers) who can take on the role of assistant supervisor.

Reflection

The quality assurance protocols described below at the university level and in more detail in the document *Kvalitetssystem för utbildning på grundnivå, avancerad nivå och forskarnivå vid Örebro universitet* (Quality system for undergraduate, advanced and doctoral education at

ORU)[3] are applied in chemistry studies. The protocol specifies the roles, responsibilities and decision levels within education at ORU. Decisions on the composition of the supervisor group is one example of quality assurance for which the head of school is responsible together with the Head of subject. Each doctoral student has an individual study plan (ISP) which is updated annually by the supervisors together with the doctoral student (for details, see section "Follow-up, measures and feedback"). During the review of the ISP, possible challenges in the supervision are also evaluated by the head of school and the Head of subject. The former also has the ultimate responsibility for taking any action needed while the Head of subject has the overall responsibility for the execution of the doctoral programme. This includes continuous contact with all supervisors and doctoral students. Moreover, as part of the quality assurance protocol a follow-up is done by the faculty board to ensure that each subject is collecting and updating the ISPs annually.[4]

In summary, we consider that the number of supervisors is adequate and the supervisor group has the skills needed to conduct doctoral education in compliance with the subject description and provisions laid down in the general syllabus. There is even sufficient capacity to receive more doctoral students, and several of the postdoctoral researchers and research fellows can be involved in the supervision. The latter is important, partly to advance the careers of individual researchers and partly to provide the subject with competent principal supervisors in the long run. In addition, it is important to also involve postdoctoral researchers and research fellows in the supervision work. One of the main reasons for this is that the doctoral studies within chemistry involve a substantial amount of laboratory work, requiring intensive supervision, especially in the beginning of the doctoral studies. Another is to guarantee the development of new supervisors in the long term. It is also essential that postdoctoral researchers are given the opportunity to supervise, as expertise on supervision of doctoral students is needed for the docentship, which, on the other hand, is a requirement for the role of principal supervisor. We also consider affiliated researchers (4 persons) within chemistry, both from industry (e.g. Waters, Fortum Waste Solutions) and other research institutes (e.g. Örebro University Hospital) to be very important for the doctoral programme. Not only does this involvement create direct links outside of academia, it also broadens the doctoral students' perspective in terms of the applicability of their doctoral studies, in addition to the actual collaborative research projects.

In terms of the competence development of supervisors, the number of doctoral students, as well as the pool of suitable supervisors for the doctoral students, we consider the dependence of the research on external funding a possible risk factor within doctoral education. If external funding is not available, it is not possible to recruit new doctoral students, and that further leads to lack of the experience on supervision of doctoral students needed for docentship, which is needed to act as the main supervisor. Although there is internal funding for senior lecturers and professors, including support for competence development (20 % for a full time teaching employment), the research is heavily dependent on external grants, and thus, there is

[3] https://www.oru.se/globalassets/inforum-sv/centrala-dokument/styrdokument/utbildning_forskning_samverkan/utbildning_grund_avancerad_forskar/kvalitetssystem-for-utbildning-pa-grundniva-avancerad-niva-och-forskarniva-vid-orebro-universitet.pdf (in Swedish)

[4] https://www.oru.se/globalassets/inforum-sv/centrala-dokument/styrdokument/utbildning_forskning_samverkan/utbildning_grund_avancerad_forskar/kvalitetssystem-for-utbildning-pa-grundniva-avancerad-niva-och-forskarniva-vid-orebro-universitet.pdf (in Swedish)

a degree of vulnerability in the long term, particularly regarding the opportunities to recruit new postdoctoral researchers and research fellows and doctoral students, thereby securing the provision of skills.

Another important aspect is how to maintain and further develop the high competence level of the research personnel. Over the last five years, recruitment has been successful, including two international recruitments at the professor and senior lecturer levels, in addition to postdoctoral researchers. Competence development and internationalisation are both listed as key focus areas by ORU. They are also supported at faculty level by additional funding for both activities and as a form of career development programme, including allocation of research time and possibility for sabbatical research visits to external research institutes. Successful competence development puts high demands on infrastructure as this is a key element both for successful research in chemistry, and to make ORU attractive for new recruitments. This requires sufficient financial support also from the university, and infrastructure has been supported over the last three years by additional funding rounds by the university. However, there is no continuous structure available for this at ORU. This part is discussed in more detail in the next section.

Conditions

Third-cycle programme environment

Doctoral education and research within chemistry at ORU is performed at the MTM Research Centre and at the Life Science Centre. The main topics are analytical biogeochemistry, applied environmental science and technology, analytical and environmental chemistry, metabolomics, biochemistry as well as occupational and environmental medicine. In addition, most of the mentioned topics are brought together in the profile Environmental Forensics (EnForce), funded by the Knowledge Foundation (KKS) as described below. At the Life Science Centre, the chemistry research is conducted in the molecular biochemistry group, which is also partly financed by KKS via the Synergy programme ‘developvaccines@ORU’. MTM and the Life Science Centre are two of ORU's strongest research environments.

MTM and the Life Science Centre have a well-equipped, state-of-the art laboratories for applied analytical and environmental studies and effect assessments with mass spectrometric instruments coupled to chromatographic systems (GC-HRMS, GC-OrbitrapMS, 3 x GC-MS, 3 x UHPLC-QqQMS, GC-QqQMS, 2 x GC-QTOFMS, 2 x UHPLC-QTOFMS, UPLC2-MS, ICP-MS, ICP-MS^3, MP-AES, IR-MS, CE, UHPLC, SEM-EDS, CIC). MTM is also in close contact and has close collaboration with three main instrument vendors (Waters, Agilent, Thermo). The effect assessment facilities include *in vitro* (AhR, oestrogen, androgen, PPAR, stress response, genotoxicity, lipid metabolism) and *in vivo* (zebrafish, collembolan, earthworm) methodologies and fractionation systems for both GC and LC to enable effect-directed analysis in combination with the beforehand mentioned MS systems. Instrumentation also includes biochemical equipment e.g. 2 ÄKTA protein purification chromatography systems, several UV/VIS spectrophotometers, 1 high-end spectrofluorometry system, 2 double

monochromator spectroradiometer systems, 2 tuneable lasers and 1 photon-counting luminescence-mode CCD camera. The chemistry division also use plant facilities, including a green house, and a class 10 clean room allows for element and isotopic analysis at background levels.

Overall, our chemistry research is done in a joint environment of chemistry, biology and ecotoxicology, rather than one with chemistry only, thus giving doctoral students an excellent opportunity for multidisciplinary in their research. This is one of the main strengths of the chemistry research environment at ORU. It might, however, require careful planning of the students' doctoral studies to obtain a sound balance between intra- and interdisciplinarity and the planning of a balanced study plan is also an essential part of the ISP.

Networking

MTM was granted a collaborative Research Profile15 by KKS entitled EnForce; with the focus set on the development of a toolbox for comprehensive chemical screening. Importantly, it includes ten industrial partners, with joint research questions and projects, thus linking the research with industry. Periodically, EnForce also organises national workshops for researchers, companies and authorities, which gives doctoral students an excellent opportunity to interact with several stakeholders, including industry and public sector.

ORU is the coordinator of a new consortium called SWACCS (Swedish Academic Consortium on Chemical Safety, https://www.swaccs.se/), based on the network of 13 different universities that were part of Swetox. The SWACCS aims at effective collaboration between academic research and education on the one side and other sectors of society on the other, and it encompasses different disciplines of science, such as medicine, engineering, social science, law, and economics.

MTM is a member of the NORMAN network (www.norman-network.net) which represents a platform to promote exchange between researchers from different countries in the field of emerging substances; thus providing an excellent platform for interaction also for doctoral students. In addition, the professors and the researchers at the chemistry department have extensive international networks.

The researchers at the Life Science Centre come from two different schools; the School of Science and Technology and the School of Health and Medical Sciences. Recently, KKS funded a KKS Synergy programme (developvaccines@ORU) for the group. The Life Science Centre is also a member of the International Society for Plant Molecular Farming, as well as of the International Society for Plant UV Photobiology ('UV4Plants'), both of which provide an excellent network for senior scientists and doctoral students alike with biannual congresses, a website, newsletter, additional workshops and networks for announcing job opportunities. Moreover, UV4Plants provides an annual methodological workshop for Early Stage Researchers (ESRs).

Project funding

There is faculty-based funding for the supervisors within chemistry in the form of research time for professors and lecturers (65% and 35-50% of full-time working hours respectively). However, most of the funding for doctoral students comes from external sources, such as the Swedish Research Council (VR), Formas, MISTRA, Vinnova, STINT, KKS, and EU's Horizon2020 (Table 1). When admitting doctoral students, the School of Science and Technology ascertains that sufficient funding is available for the entire doctoral education period. When funding is available for a shorter period, e.g. 3 years (as is often the case with e.g. Formas as well as several other funding agencies), the project is suitable for licentiate studies. If further financing is obtained, as is the case for in principle all of the cases (e.g. from minor funders, see Table 1), the doctoral student has the option to apply to continue their studies to obtain a doctoral degree. The faculty also has specific funding targeted at doctoral students, typically used for covering travel costs, thus guaranteeing the possibility to attend 1-2 international conferences annually throughout the doctoral programme, in addition to possible funding within the projects. Generally, participation in a minimum of two international conferences during their doctoral studies is required.

Table 1. Overview of the project funding within chemistry.

	2015	2016	2017	2018	2019
International non-profit organisations	255964	1678592	3064306	4855801	6297339
Formas	562356	1808560	3973442	4524723	3613721
Swedish authorities	1227261	1442903	2386488	2885591	3366046
EU grants	868081	335633	1508376	3111962	2372223
The Knowledge foundation	2600501	1199257	200603	-290888	542078
International corporations	-209846	22168	-464805	405177	519004
The Swedish foundation for international cooperation in research and higher education, STINT			161939	37101	340773
Vinnova		2345	540648	1051145	318118
Private individuals					290140
Swedish corporations		9029	13483	9567	147565
Swedish research council		118104	659606	705599	70549
Region Örebro county	80463	87622	117322	586044	53330
MISTRA		29719	32924	419	14096
Higher education institutions	3124	53042	1063		
Swedish non-profit organisations			30293	19707	
Other Swedish municipalities			172790	67210	
Other Swedish counties		25000			
Other Swedish non-profit organisations	245424	856351	305376	706722	
Other Swedish authorities	373531	26541			
TOTAL	6006859	7694866	12703854	18675880	17944982
Ratio of grants versus direct funding, %	43	47	58	65	74

Quality of research

During the period of 2015-2019, 212 articles (205 research articles, 7 review articles) were published in peer-reviewed journals. The trend of publication was significantly increasing from 2015 (30 articles) to 2019 (61 articles). Of those articles, doctoral students co-authored 51 articles, and the majority of these were part of their doctoral theses. The publication outlets including impact factor (IF) and doctoral student involvement are listed in Table 2 below.

Table 2. Overview of the publications within chemistry, selected journals

Journal	IF	Doctoral student involved
Nature	43.07	
Cell	36.22	
Journal of Hepatology	18.95	
Cell Host and Microbe	17.87	
Nature Communications	11.88	
Nature Protocols	11.33	
TrAC. Trends in analytical chemistry	8.43	x
Plant Biotechnology Journal	8.15	
Environment International	7.94	x
Environmental Science and Technology	7.15	x
Plant, Cell and Environment	6.36	
Analytical chemistry	6.35	x
Environmental Pollution	5.71	x
Chemosphere	5.11	x
Environmental Research	5.03	x
Talanta	4.92	x
Ecotoxicology and Environmental Safety	4.53	
Environmental health	4.43	
Journal of chromatography A	4.17	x
Scientific Reports	4.12	

Reflection

The faculty, division and the supervisors all have key roles in quality assurance, as also specified in detail in the document *Kvalitetssystem för utbildning på grundnivå, avancerad nivå och forskarnivå vid Örebro universitet*. The faculty board approves the general syllabus for doctoral programmes, while the course syllabi on the programmes are approved at the school level. The faculty board also conducts recurring internal quality reviews of subjects/main fields of study, as well as other reviews of individual aspects of the doctoral programmes. The last follow-up of chemistry at undergraduate level was done in 2016- 2017. The next follow-up is planned for 2022.

Research at ORU has been evaluated internally in 2010 and 2015, and the next evaluation, ORU 2020, is currently in progress. In the latest evaluation, ORU2015, chemistry was found to have one of the highest overall international standings of the evaluated subunits, being in the top 10% relative to Swedish researchers. It was further found that "*the chemistry projects*

are significant and the problems dealt with are very relevant in today's society. Based on the bibliometric analysis, vitality is the highest among the evaluated subunits." Compared with the evaluation period of the 2015 evaluation, the number of publications within chemistry has increased from approx. 24 articles/year to approx. 43 articles/year (2015-2019), with a growing trend also over the last five years. High-quality research is a prerequisite for high-quality doctoral education.

One of the tools for ensuring high-quality doctoral education, in addition to overall education and research, is done by the annual setting of the goals at the university level, and more specifically, at the faculty level. Here, a risk analysis, that includes the possible risks in personnel, infrastructure and external funding is performed, and an action plan is prepared. For example, within natural sciences, one of the main risks, related to high-quality doctoral education is considered to be the maintenance of the current high level of infrastructure, as this also helps us to 1) maintain sufficient external funding, 2) develop existing international networks, 3) attract new recruits (doctoral students but also research and teaching personnel) of a high national/international standard.

Overall, we consider the research environment at ORU to have excellent facilities for doctoral students, both in terms of instrumentation and for interaction with researchers, both nationally and internationally, as well as with industry and relevant authorities within the field of chemistry. One of the potential risks is, however, that the doctoral student becomes overly dependent on the supervisor or that the supervisor does not have sufficient time or expertise for the supervision task. This is already considered during the selection of the supervisor group, so that the principal supervisor and the assistant supervisor are not heavily dependent of each other. The doctoral student has the possibility to change supervisor(s). This is taken into consideration by the Head of School and Head of subject. Moreover, in case any issues are observed in supervision, either during the annual review of the ISP, or in other formal/informal discussions, corrective measures can be planned. For example, additional assistant supervisors can be selected if more competence within specific areas of the research is needed, or in case some of the supervisors are not able to provide sufficient supervision due to e.g. leave of absence or a change in career plans.

The infrastructure has been updated significantly during the last four years, both by means of internal university funding and through the successful external funding from KKS. However, one of the key issues is the sufficient updating of the instruments as well as instrument maintenance. The latter is not generally covered by the university, but through the projects, and instrument break-down can cause major delays within both research and doctoral studies. This has been brought up by the doctoral students in the discussions, identified as the major potential challenge in their research. The faculty is currently investigating possibilities for a sustainable strategy for maintenance. It is also essential that national and international opportunities for infrastructure funding (e.g. VR, EU) are utilised in a more efficient manner. The chemistry division is currently involved in preparation of a large infrastructure application to the EU. However, relying on external funding only is risky and therefore, improved internal financing tools should also be considered. Here, getting a sufficient critical mass of research carried out over faculty borders is a possibility, and we have started several joint projects with

e.g. the School of Medical Sciences as well as with Örebro University Hospital. We have also initiated discussions on joint infrastructure.

Overall, we consider that the main strength of the chemistry research at ORU, and thus, the doctoral education in chemistry, is that the research environment consists of not only chemistry, but also of biology and (eco)toxicology - which are working closely together not only in theory but also in practise - with shared laboratories and shared expertise. This is further supported by close links with industry.

Design, implementation and outcomes

Target attainment – knowledge and understanding

The intended learning outcomes for the award of the degree, specifically, the qualitative targets, are stated in the ASP for the doctoral students. Generally, for the Degree of Doctor, the third-cycle student shall demonstrate specific knowledge and understanding, competence and skills within their own field of specialization as well as skills related to critical judgement and research approach in science in general. In order to obtain the goals, the doctoral student can tailor their studies to meet the qualitative targets, learning outcomes and learning activities. This is done under guidance of the supervisors.

For covering the knowledge and understanding of the general aspects of the research, we have the compulsory courses for all chemistry doctoral students, regardless of specialisation, including the course *Research and Thesis Planning in Science and Technology* (Forskning och avhandlingsplanering i naturvetenskap och Teknik, 7.5 credits). This goal is naturally further supported by the actual research work and the articles written during the doctoral studies. For the two specialisations, i.e. in life science and environmental science, the compulsory courses include either *Life Science Seminars* (Livsvetenskap – seminarieserie) *Preparatory* Paper (paper – basic literature course in chemistry, 7.5 credits). Most of the other doctoral students select the latter course also as an elective course, as the course gives a very good background for them, required in the process of writing of the scientific results of their doctoral studies. Together these courses, combined with the research work and scientific writing help the doctoral students to gain knowledge and understanding both in scientific work in general as well as skills within their own field of specialization.

The learning goals are further supported by the elective courses which are divided into two blocks, namely Block I: Methodology courses, and Block II: Specialized and complementary courses. Students can also include relevant courses from other universities following consultation with the supervisors and the Head of subject. Individual tailoring of the study plan, in collaboration with the supervisors and if needed, with the Head of subject, makes it possible to choose those courses that give specific knowledge on the area of research if individual students. For example, doctoral students focusing on e.g. metabolomics can choose courses (typically external) that cover that area while students working with microplastics can choose courses related to polymer chemistry. In practise, several students have taken courses

outside ORU, for example, *Techniques for the Detection of Organo-Chemical Pollutants in the Arctic Environment* at the University Centre in Svalbard (three-week course) and *EMBO Practical Course on Metabolomics* organised by the International Agency for Research on Cancer in Lyon (one-week course). The faculty funds the travel costs for such training. Currently, as majority of such courses are organised on-line, making it even easier for the doctoral students to select external courses.

More specifically, the elective courses include methodology courses, with a focus on methods used in chemistry research, including statistical methods, planning and evaluation of experiments. An example of courses is *Multivariate Statistics and Experimental Planning* (Multivariat statistik och försöksplanering), 7.5 credits. Statistical skills are required in most research projects within doctoral studies in chemistry. The specialised and complementary courses cover courses not only in chemistry but also in other relevant subject areas and are geared towards the specific thesis project and the specific knowledge needs of the individual student. On the other han, an example of a general course that includes methodologies that in principle all the doctoral students in chemistry need is *Advanced Organic Mass Spectrometry* (Avancerad organisk masspektrometri, 7.5 credits).

PhD courses are also offered via the SWACCS network (https://www.swaccs.se/education), including courses on entrepreneurship. Currently, several new courses are planned at the doctoral level. In 2019, the SWACCS Junior Academy Workshop was organised at ORU, on 16-17 September. Several doctoral students from ORU attended the workshop (7 on total, of those 5 in chemistry) in order to strengthen their network in areas related to chemicals, health and the environment. The workshop also included a doctoral course in research communication of 1.5 credits.

Peer-learning and learning within the projects

Many of the doctoral students in chemistry are performing their research within a larger project as described above, that includes both national and international collaborators with multidisciplinary expertise. Thus, in these projects the students will collaborate with international researchers and doctoral students that may have complementary expertise. For example, one of the doctoral students is funded by the EnForce project and is working with development of methods for the determination of side-chain fluorinated polymers in collaboration with two companies: landfill leachates samples are provided by Ragn-Sells and method development is done in collaboration with Eurofins. Another example is a VR-funded project on exposome, which is done in collaboration with the Faculty of Medicine and Health and several international research groups (Finland, Norway, USA, UK), and which combines environmental analysis, metabolomics and bioinformatics. The doctoral student has been making research visits to one of the collaboration partners for individual training on bioinformatics tools.

Peer-learning from other doctoral students as well as from more senior researchers (e.g. post docs) is also an essential platform, particularly in terms of methodological aspects, as well as in terms of presenting and discussing your work. The day-to-day collegiate co-existence provides many opportunities for knowledge transfer between doctoral students and with other

researchers. Indeed, one of the most important practical ways of learning instrumental techniques, instrument maintenance and data processing is via knowledge transfer between doctoral students themselves, as well as with other researchers. This contributes to the intended learning outcome relating to supporting the learning of others being met, as the doctoral students teach the methodology to more junior students.

The doctoral students can attend public defence events and seminars where their colleagues present their work, thus getting a wider view of research. Also the supervisors attend these seminars. In addition, MTM and the Life Science Centre organise seminar series within both chemistry and biology with international guest researchers, funded by the faculty. These seminars aim to provide broader knowledge of the subject as well as to facilitate new collaborative projects and networking. In chemistry, we have organised a seminar series with international guest speakers, having typically 7-10 visitors annually. In 2019, we hosted 7 seminars, with guest lecturers from Sweden, Norway, Croatia, UK, Canada and USA, covering topics from environmental chemistry and analytical chemistry to the teaching of chemistry. The doctoral students can also suggest guest lecturers. The seminar series has resulted in novel collaborative projects. For example, as a result of one of the guest lectures, we have started a collaboration with Boston University with one of the guest speakers as part of a study for one of our doctoral students. In 2020, due to the travel restrictions we organised the seminars remotely, by organising joint doctoral student presentations with other collaborators in order to promote peer-learning from other doctoral students from Austria, the U.K., the U.S., Norway, Sweden, Canada, Hong Kong, Mainland China. Senior staff were also participating to these seminars, giving feedback of the research methods and presentation skills of the doctoral students.

Reflection

The faculty board approves the general syllabus for the doctoral programme. Any changes must be approved by the board. At the individual level, goals have to be specified in the doctoral student's ISP, with progress towards goal attainment reviewed at annual follow-ups during the studies. Follow-up is also done through regular meetings with the supervisors, typically taking place 2-4 times/month. The annually updated ISP is reviewed by the head of school and the Head of subject and particular attention is paid on the progression of the individual students achieved during the program.

Overall, we consider that the workflow for quality assurance has been efficient, also based on the facts that the doctoral students finish their studies within the expected timeframes. The theses are generally of high quality as a majority of the sub-studies have been published (or are later published, in the case of submitted work) in peer-reviewed international journal series. Moreover, our doctoral students have good employment prospects after finishing their studies (see the section on Links to the world of work), which is testament to the doctoral programme meeting its aims and objectives. The methodical approach offered by the ISP can help the supervisor(s) in their work and give the students a clearer picture of what is expected of them. Tracking progress on the fulfilment of the intended learning outcomes contributes to the effective monitoring of the students' education as a whole and facilitates the student-supervisor dialogue. It should be noted that the design and content of the doctoral programme

is tailored to each doctoral student, and the fulfilment of a student's intended learning outcomes for the award of the degree, and ambitions of scientific autonomy are particularly dependent on the student's own powers of initiative as regards self-development and the development of others, including interaction with society in general.

Based on feedback from doctoral students and their supervisors, it is important that the course portfolio can be planned individually. Due to the wide range of individual research topics in chemistry, we have considered that this is best guaranteed by having a sufficient proportion of elective courses. For more general courses, courses related to academic leadership as well as to teaching and learning are advantageous, and doctoral students are encouraged to also select these courses. Doctoral students have also stressed that the courses should be planned in such a way that it is possible to take them alongside the research elements of the doctoral studies, including laboratory work. This is not always easy to plan, again as the individual projects have very different time schedules and project plans.

We consider that we cover the methodological aspects of the programme well, related to both instrumental techniques and statistical methods, as we have access to solid expertise and offer lectures covering these areas. The lecture courses are further underpinned by peer-learning, as the research personnel are highly competent with regard to instrumental techniques. Moreover, there is close collaboration, e.g. through the EnForce project, with instrument vendors. In general, however, the doctoral students have given feedback on the rather limited number of courses arranged at ORU for doctoral students, and the challenges of combining research work, mainly the experimental part, with some of the courses offered. We have acknowledged this concern and have discussed different practical scenarios. The reason for the limited number of chemistry courses at the doctoral level is due to the wide range of individual research topics covered at ORU, and highly specialised courses would include only one or two doctoral students, which is not a very viable option. Therefore, the course portfolio has been discussed at the division level, as have the challenges (financial, number of doctoral students in specific topic areas), and we have considered that the best option is to utilise our networks, such as SWACCS, for creating more specialised courses. The quality of the courses organised by us at ORU can be evaluated in terms of their content and intended learning outcomes. For courses organised outside our university, this is more challenging. However, we carefully evaluate the course content and the scientific level of the organisers in order to ensure that the level is appropriate and that the content enables the student to meet the intended learning outcomes given in the ASP. Doctoral students can receive faculty funding for the chemistry discipline to facilitate participation in external courses. Moreover, some of the doctoral courses are arranged in such a way that they are suitable for doctoral students across the different disciplines of natural sciences (e.g. the "*Preparatory Paper*" course).

We are currently developing more methodological tools for both further development of the doctoral programme and for risk assessment and action plans in case of any problems in reaching the intended learning outcomes at the individual level. In the first instance, this is done in the committee of supervisors together with the Head of subject, and later on at more formal levels. Moreover, we will start organizing an annual meeting for the doctoral students in chemistry in order to provide opportunity for the students go give input in development of the doctoral education. The goal is to develop a workflow both for early detection of any issues

at the level of individual doctoral students and for corrective measures, as well as to perform an overall risk analysis.

Design, implementation and outcomes

Target attainment – competence and skills

Planning and conducting the research

Planning the research work is one of the main tasks throughout the doctoral studies. In general, during the course of the doctoral studies, the doctoral student, with the support and guidance of their supervisors, will formulate a research question, develop a plan, select and apply appropriate methods, and analyse and report the results - typically in the form of scientific publications, which are then finally summarised in the thesis. In the beginning, the doctoral student is generally responsible for planning the methodological part themselves, while more support is given at the data analysis and writing stages. Towards the end, the doctoral student takes the main responsibility for the whole workflow. Each publication can be considered a separate task with research questions, planning towards a deadline, making methodological choices and decisions on authorship and presentation. This is "examined" through the review process of the journals and conferences and, for the thesis as a whole, through the defence of the thesis. An external review is carried out at least three months before the defence in case not all the papers have been reviewed and accepted/published before the defence. Many of the doctoral students work in larger projects where additional requirements are set for planning and organisation. The research plan and the sub-studies are described in the ISP by the student and supervisors, and are reviewed every year by the student and supervisor, as well as by the faculty, as described in detail further on in this self-evaluation.

Among the courses, the compulsory course *Research and Thesis Planning in Science and Technology* constitutes an important starting point for doctoral education. The purpose of the course is, among other things, for the student to be able to:

- Identify and summarise requirements for a doctoral/licentiate thesis and use these to assess their own work.
- Identify needs for new knowledge in the chosen area.
- Formulate a dissertation project and specify the steps and timetable for the research.

The course consists of lectures, seminars and individual work.

The intended learning outcomes above are examined through the student preparing and reporting on a literature review; preparing a research plan in the form of a "one-pager"; a Gantt chart for the work leading up to the licentiate or mid-way review, and a poster describing the research project.

There are also several courses that cover the intended learning outcomes related to research methodology, such as *Multivariate Statistics and Experimental Planning*, *Advanced Organic Mass Spectrometry* as well as *Chemometrics - Statistics for Chemists*. These courses, together with the learning within the projects and via collegial support and teaching, help the students to reach the intended learning outcomes relating to methodology.

Presentation of the research results

Scientific communication is practised and examined in various courses with seminars and/or writing assignments, as well as at other seminar presentations. For example, the above-mentioned course *Research and Thesis Planning in Science and Technology* includes the intended learning outcome to "demonstrate ability to analyse, present, review and discuss scientific material". This is practised during the course's learning activities in the form of seminars and individual written work and is examined through students presenting their solutions in writing and orally (see the description of one of the course's examination elements above).

The university also offers a course on *Academic Writing*. This course aims at providing the doctoral student with knowledge on the scientific publishing process and includes exercises and practical training on writing and analysing scientific texts. The intended learning outcomes include advanced proficiency in retrieving, summarising, reviewing and writing scientific texts, as well as advanced proficiency in oral communication of scientific reviews.

Presentation of the research results is practised at several levels during the doctoral studies. The writing of conference presentations/proceedings, publications and, ultimately, the thesis are the main forms of written presentations. The doctoral students get feedback from their supervisors, co-authors, the article reviewers, as well as from the pre-reviewer and reviewers of the thesis. One of the main tasks of the supervisors is to give guidance on how to respond to the critique from the reviewers in a constructive manner. For oral presentations, the internal seminars as well as international conferences and workshops are important opportunities for developing the ability to present and discuss research and research results. All doctoral students have to participate in at least one conference or workshop during their doctoral studies, and most doctoral students participate in at least one conference/workshop per year, supported by faculty funding. The doctoral students are invited to practise their presentations before the conference within the group, getting feedback on their presentations. After the conference, they are asked to give a short report on the conference to the group members.

In addition to attending international conferences, doctoral students are encouraged to seek and apply for shorter research visits abroad, through for example the Erasmus programme. Typically, these research visits involve the student spending 1-2 weeks in another laboratory, aiming at gaining experience in discussing research with other scientists and achieving an international perspective on their research topic. For example, over the last two years, our chemistry doctoral students have spent time in Finland, Australia, the Netherlands, Belgium and China via either project financing, Erasmus or STINT funding.

Several doctoral students have the opportunity to teach at the undergraduate level, which is an efficient way of learning how to present scientific methodologies in a constructive manner. In practice, majority of the doctoral students (excluding the industrial students) participate in teaching. An exception from this are typically the externally employed doctoral students who cannot usually set aside time for teaching assignments, as their research is usually linked to the needs of their companies. The nature and scope of the teaching is documented in the ISP, and the time allowed for the doctoral studies is extended by the corresponding amount of time. The university offers a course organised by the Centre for Academic Development called *A Practical Introduction to Teaching* (Praktisk pedagogik för nya lärare, 2 weeks). This course gives an opportunity to practise hands-on and concrete student-focused ways of lecturing, holding seminars or providing supervision. It also provides tools for managing challenging and unexpected situations in the classroom.

Communication with the general public and society

In communication, one important study goal of the doctoral studies is related to the third task of the university, i.e. how to make the research results accessible and understandable for various communities outside the academia. This requires similar skills as described above, however, a slightly different aspect is required in the presentation of the results to other stakeholders, such as general public and industry. ORU organises courses on the topic, and the doctoral students also have several additional possibilities to learn and practise these tasks, as described below.

The Innovation Office at ORU offers a doctoral course in utilisation of research results, *The Utilization of Research*, of 4.5 credits. The course covers how to reach the wider community by embedding non-academic impact strategies in the projects, by working with a range of non-academic partners, and by using ever more innovative methods of dissemination and utilisation. The course also provides students with tools that will help them best communicate the value of their work to research funding bodies and potential investors. MTM also has extensive contacts with the surrounding community in the form of research projects. Students are encouraged to and often participate in public meetings and national networks, including with municipalities, government agencies and other stakeholders. As many of the research projects at MTM include industrial partners, this gives doctoral students a good learning opportunity to present their results to different types of target groups.

We also have a specific course on *Research Communication in Chemicals, Health and Environment (1.5 credits)* where the aim of the course is to give doctoral students tools to develop an understanding of the significance of being able to communicate academic research in the field of chemicals, health and the environment, as well as knowledge on how this can be beneficial for society, industry and academia.

Another examples of a course within this topic is *SWACCS – Research Communication* Course (1.5 credits) as part of the SWACCS Junior Academy workshop. Several doctoral students, as well as postdocs (25 persons) both from ORU and from other universities participated on the workshop. This course covered writing and presenting one’s thesis or project work using suitable methodology and popular-science language. It is part of a theme on ‘Career

development within chemicals, health and environment'. Invited speakers represent the trade union, are consultants in sustainability, retail business and academia. Preparation before the workshop was an assignment to prepare a one-slide presentation following the Need, Approach, Benefit and Competition model (presented during the workshop). Presentations and group work activities focused on how to create a research presentation, identification of stakeholders, and build research networks were included in the course. After the actual course programme, students submitted a written self-evaluation assignment. The goal is to have the course arranged on a regular basis.

In addition to more formal forms of presentation and courses, the doctoral students in chemistry (and other subjects) have also given presentations on more informal occasions, such as at the 'Science Pub' (*Vetenskapspub*), which is organised in a local pub and is aimed at the general public. Our doctoral students have also been interviewed by media, for example, most recently in October 2020, one person was interviewed for TV4 on her recently finished thesis.

Reflection

It is important that the doctoral student and the supervisor together reflect upon the student's academic progress and what they need to do to ensure that the doctoral student meets the intended learning outcomes. The follow-up measures intended to assess whether the intended learning outcomes are met include the examination of the courses and the ISP. The doctoral student, together with the supervisors, set the annual goals during their ISP planning, including the plans for the publications. Goal attainment is also followed-up during the annual review by the head of school and the Head of subject. Any deviations from the plan or delays are then discussed, and supportive measures can be taken, if needed. Some doctoral students may need more support in meeting the intended learning outcomes, for example, many doctoral students need more assistance in their academic writing. In addition to courses organised in academic writing, doctoral students can get more help from their supervisors, and if needed, also in the form of academic writing support at the University Library. Typically, the doctoral students do not have any problems passing the required courses, and thus, do meet the criteria set on the courses. If needed, more time can be allocated for the studies. As the majority of the doctoral students are keeping their time schedules, we can conclude that the workflow in general is functional.

The intended learning outcomes related to presenting the research are examined through the seminar presentations given by the doctoral student, as well as through the publications, and finally through the defence of the thesis. The supervisors have a major role in the quality assurance of this part. It should be noted that every thesis are compilation theses, where individual works are reviewed before publication. Unless all the papers have been reviewed and accepted/published before the defence, an external review is carried out at least three months before the defence. Typically, the presentation of the results to general public/society is more challenging to follow-up, as not all doctoral students have projects that would naturally involve communication with other target groups.

Quality assurance of the thesis examination is done in several ways before the actual defence. First, we have a recommended number of articles that are to be included in the thesis.

Typically, at least four articles should be included, with the doctoral student as the first author in the majority of these publications. At least two of the articles should have been accepted for publication in peer-reviewed international journals. Any exceptions are discussed with the Head of subject. In practice, all thesis meet these requirements. Secondly, the doctoral student conducts 2-3 seminar presentations as checkpoints of their studies during the doctoral programme. A majority of the doctoral students also have presentations in both internal and external workshops and conferences. A seminar is conducted at the beginning of the studies when research issues and a thesis plan are presented. A seminar is also held shortly before the defence of the doctoral thesis. The seminar presentations are followed up with comments and feedback. Other doctoral students and supervisors can attend and comment at these seminars. Thirdly, two months before the defence, information related to the fulfilled criteria of the doctoral studies, including the papers included in the thesis, are filled out in a form. The thesis is proofread by the supervisors prior to being submitted to the external reviewer. If considered necessary, additional readers can be used before the thesis is sent to the external reviewer. At the time of a doctoral student's thesis defence, their supervisor confirms that the intended learning outcomes as set forth in the Higher Education Ordinance have been met, as demonstrated by the student's thesis and its defence. The intended learning outcomes containing a social component and giving evidence of an ability to interact with the wider community must be met but are not subject to formal examination.

In summary, we consider that our doctoral programme provides the doctoral students with the skills required for planning and conducting high-quality research within chemistry. As stated earlier, the theses are generally of high quality, as a majority of the sub-studies have been published (or are later published, in the case of work submitted during the thesis-writing process or after the defence) in peer-reviewed international journal series. Moreover, the doctoral students generally find good employment after finishing their studies at ORU (see also the section on Links to the world of work), which also supports that our doctoral programme meets the criteria laid down.

During the doctoral studies, the main focus is on scientific research, including both the actual research and the presentation of the scientific results. Our students are offered good opportunities to learn and demonstrate their skills during their studies. We consider most of our doctoral students in chemistry to show very good presentation skills. Some of the doctoral students have also been interviewed in media. Presentation of the results to a more general public is a smaller part of the doctoral studies, and this is highly dependent on the individual projects. It is possible that we should put more emphasis on this part of the programme, as a general improvement.

Those doctoral projects that are performed in collaboration with industry create possibilities for practising more general ways of presenting research. However, this does not include all doctoral students, especially those focusing on more fundamental scientific questions. The majority of the doctoral students participate in teaching at the undergraduate level, although the degree of teaching varies quite substantially between individuals. Teaching should not exceed over 20% of full-time working hours.

Design, implementation and outcomes

Target attainment – judgement and approach

Intellectual autonomy and scientific credibility are crucial learning goals in the doctoral education, together with research ethics. These targets are important to address through the research projects, and also specific courses related to the learning targets are available.

The role of supervisors is crucial in the development towards intellectual autonomy, and this goal is continuously evaluated during the research projects. It is important for supervisors to find the right balance for support and encouragement during the course of the doctoral studies. In general, the doctoral students should take increasing responsibility for their research over time, including choice of method, implementation, analysis, article authorship, handling feedback from reviewers and following developments in their research area. With increasing experience from conferences, meetings, research visit, seminars and other activities discussing research, the doctoral student gradually develops towards the intellectual autonomy goals. In the introductory chapter of the doctoral thesis, the doctoral student is expected to describe his/her role in and contributions to each of the publications included in the thesis. This information must also be enclosed when the application of the defence is submitted to the Office of Academic Policy in cases where several persons have contributed to the publications included in the thesis, as is typical in chemistry. Regular follow-up is done via the ISP, for example through the author list for planned manuscripts. Intellectual autonomy is also one of the critical evaluation criteria in the review of the thesis by the external reviewer and the examining committee.

Scientific credibility is a cornerstone of research quality and it includes responsible conduct of research. Here, the supervisors and research environment play a significant role in promoting the norms of responsible conduct of research. We have also two doctoral courses related to the topic, *Research and Thesis Planning in Science and Technology* (7,5 credits) and *Research Ethics in Science and Technology* (Forskningsetik inom naturvetenskap och Teknik, 2.5 credits), both of which cover the main aspects of this objective.

The compulsory course *Research and Thesis Planning in Science and Technology* provides an introduction to research and doctoral studies. On completion of the course, the doctoral student should be able to demonstrate the ability to identify the need for further knowledge within the chemistry field, using sufficient scholarly precision and appropriate methods. The doctoral student should be able to demonstrate the ability to evaluate and argue for the relevance of the project in relation to current research issues, as well as to evaluate research-ethical implications of the proposed thesis project.

The second course of relevance is *Research Ethics in Science and Technology*. It is not obligatory, but in practice a majority of the doctoral students is taking the course. The course provides an overview of the ethical issues associated with research in natural sciences and engineering. This includes the philosophical, moral and ethical considerations in research. The course discusses:

- What is considered good research practice and professionalism?
- Ethics in scientific publication
- Ethics of animal and human studies and ethical permits
- Ethical and legal aspects of handling personal data
- Intellectual property
- Research misconduct and cheating and the responsibility for reporting such misconduct
- Regulations and legislations associated with research

The course consists of lectures, seminars as well as of individual and group assignments. The intended learning outcomes of the course include 1) the ability to judge what is ethical and what is unethical in research, 2) the ability to assess when ethical permits are required in research, 3) the ability to determine how to handle various types of research materials and information in an ethical manner, 4) an understanding of the responsibility for reporting scientific misconduct and how to do so, 5) and familiarity with regulations and legislation for selected research topics.

Several of the goals for the doctoral education as stated in the ASP are also closely linked with reporting on and writing publications. For example, in studies involving animal or human samples, the ethical permits have to be considered in the planning of the study protocols, and they have to be accounted for in the ISPs as well as in the articles. This provides a good opportunity for many of the students to learn the correct workflow during the doctoral studies. Understanding the possibilities and limitations of the scientific approach selected is also an important part of the manuscript preparation. Typically, many of the publications require a chapter describing the limitations of the study set-up e.g. due to analytical coverage/sensitivity, number of samples analyses etc. Again, the roles of supervisors and co-authors are crucial in assuring that the scientific standards are met and in evaluating whether standards of research quality and responsible conduct of research have been met.

Reflection

We already have a methodical approach for tracking progress of the outcomes met and we are currently further developing this in order to guarantee goal attainment and, importantly, to better identify the risks and possible bottlenecks on the doctoral programme.

We consider that goal attainment is generally well ensured through the content and implementation of the programme. The qualitative targets of the scientific autonomy are evaluated by the output of the research papers, as the order of authorship already specified the role of the doctoral student, and this is also specified in the doctoral thesis. This is also followed-up regularly by the ISP, specifically by evaluating the courses taken in this topic, and the feedback from the doctoral student and the supervisor. Good scientific practices, and overall scientific credibility, are also considered throughout the doctoral studies, from each sub-study/article to the final thesis. Particularly, the research ethics has a crucial role and for

that, ORU has a Research Ethics Council. The university has also guidelines for dealing with suspected misconduct in research.[5]

As part of the public defence, the supervisors have to provide the examining committee and the external reviewer with an evaluation of the doctoral student's autonomy, and how this has developed over the course of the doctoral studies. Based on the feedback, the doctoral students show quite high variation in their scientific development, as expected, but overall, all students have sufficient skills by the end of their doctoral studies. An area of development could be the implementation of clearer time frames for the seminar presentations given by the students. Currently, the students have presentations at the beginning and the end of their doctoral studies, and a majority of the students have one to two presentations throughout their project work. However, the guidelines for this are not very clear. We are currently setting up more structured guidelines for the number, type and timing of the presentations required. The committee of supervisors have regular meetings (twice/semester) to discuss the doctoral education. This is also essential in order to guarantee that doctoral students are not overly dependent on their supervisors, as this can be problematic. Moreover, using a mentoring system for new supervisors would be a viable option.

Design, implementation and outcomes

Gender equality

The doctoral education in chemistry follows the general recommendations of gender equality as specified by the university guidelines. Specifically, the ORU's action plan for gender equality[6], focuses on three development areas: 1) content and implementation of courses and study programmes; 2) research conditions and career paths; and 3) management and support processes. For these areas, different development needs and measures are specified, for example creating a university-wide conceptual definition of what gender equality perspectives mean in education and developing different forms of knowledge support and teaching for gender equality in education and research. Centrally initiated development work has begun for these areas. A new action plan for 2020-2023 is currently being developed. Within doctoral education in chemistry, of the three main development areas, the two latter ones are considered the most relevant, mainly based on the current gender balance of the doctoral students.

ORU has a policy of striving for gender balance in doctoral education. This is highlighted in the advertisement of job opportunities and taken into account when recruiting. When announcing vacancies, and applicants are found to have equal qualifications, preference is given to applicants from the underrepresented sex, i.e. if the proportion of either female or

[5] https://www.oru.se/globalassets/inforum-sv/centrala-dokument/styrdokument/utbildning_forskning_samverkan/forskning/oredlighet-och-allvarlig-avvikelse-fran-god-sed-i-forskning-utredning-vid-misstanke-riktlinjer.pdf

[6] Handlingsplan för jämlikhet och jämställdhet vid Örebro universitet 2014-2015; Handlingsplan för jämställdhetsintegrering vid Örebro universitet 2017-2019.

male doctoral students in the subject is less than 40 percent. The same wording can also be found in the general syllabus. ORU has a requirement that both genders should be represented in the examining committee at the public defence unless special reasons exist. The basis for gender equality in education is that students are treated equally, that everyone feels equally worthy, and that everyone's experiences are taken into account, for example, in seminar discussions. Gender equality is also addressed in the course for supervisors, with one specific topic including diversity in doctoral education: equality, gender and cultural differences. In the event of suspicion of a misconduct related to equality, a report must be made. Anyone can report a case for further investigation. All applications must be submitted to the vice-chancellor and sent to the registrar. The university lawyers at the Management Office will further investigate the matter.

Currently, gender distribution for doctoral students in chemistry is as follows: 61% women and 39% men. Over the last five-year period, including the students finishing their doctoral studies during this period, the gender distribution is very similar (63% women). This reflects the gender distribution on first-cycle courses and study programmes. However, as gender balance has not fully been achieved, men are considered to be the underrepresented sex on the doctoral programme and this is considered in the selection of new doctoral students. The gender distribution among staff at different levels gives the doctoral students good examples from both genders: one of the three professors is female, and there are 3 male and 4 female senior lecturers. The gender balance is also considered in the selection of supervisors, mainly related to the selection of co-supervisors as due to the external funding of the doctoral students, the main supervisor typically is the person in charge of the externally funded project.

Gender equality is addressed in the course *Research and Thesis Planning in Science and Technology* – it is included in a lecture and the students read, present, and discuss a paper on gender equality in academia. We have acknowledged that gender aspects can also be due to unconscious bias, e.g. related to the selection of research topics, however, there has not been any indications of any clear biases have been observed or reported. In research, gender issues may be relevant in some of the studies, *e.g.* in exposure and medical studies due to different patterns in different genders. This is typically considered and accounted for in the study set-up. For example, in clinical studies, the gender distribution should be equal, unless specific impacts of gender are studied.

At ORU there is a Collegium of Equal Opportunities and Gender Equality which is responsible for the university's strategic equality efforts. One of their tasks is the integration of gender issues in doctoral education. A university-wide group of researchers in doctoral education has been formed to exchange experiences and work on developing gender equality aspects in doctoral education. There is also an Equality Committee whose task is to be a driving force in the university’s work on equality. The council members are appointed by the vice-chancellor and are experts on various aspects of equality. The university has a three-year action plan for equality, including gender equality, which among other things concerns equality in the allocation of research funding and the recruitment of research staff. In June 2020, ORU, together with six other universities, organised a web conference on how the quality of research can be strengthened through gender mainstreaming of internal research resources. By hosting the conference online, some of the country's leading experts were able to give presentations

on quality, research, research funding and gender equality. The target group was deans, research leaders, heads of department, heads of division, controllers/finance functions, members of the research board and others who participate in decisions and the allocation of internal research funding. The issues raised at the workshop will be taken into account in the further development of the doctoral education. At the School of Science and Technology, the university has been engaged in organising a specific seminar on gender equality and equality issues. The seminar was accompanied by group discussions on the topic. There are also plans to organise seminars with examples from successful gender equality work within organisations and operations similar to ours.

The faculty board recently performed a study in order to evaluate whether gender has an impact on productivity, evaluated in terms of number of publications. This is followed-up annually. In chemistry, in 2018 and 2019, women accounted for 50% and 46% respectively of the staff members in chemistry, and they contributed to 57% and 76% of all the publications in 2018 and 2019 respectively. ORU has launched an online feature for whistleblowing. The feature is part of the efforts to maintain a work climate where gender equality, openness, trust and respect permeate our working environment and where irregularities are taken seriously.

Reflection

Overall, we can conclude that gender distribution in chemistry is relatively equal, currently having a slight over-representation of women on the doctoral programme, thus reflecting the overall gender distribution also among undergraduate students. The gender distribution will be taken into account in the selection of new doctoral students. Reflecting the gender distribution of senior lectures and professors, as well as other researchers with a doctoral degree, the situation is well balanced. At this level, the evaluation made by the faculty showed that scientific productivity, measured by the number of publications, also showed higher productivity for the women. We have not done a detailed analysis of the course materials in relation to gender aspects, which might be useful in order to illustrate any unconscious bias in terms of gender equality. This will be one of the areas for discussion in the committee of supervisors.

Design, implementation and outcomes

Follow-up, measures and feedback

The university has an internal quality assurance system based on the *Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG)*, from 2015. The faculty board is tasked with the follow-up of the student's union's work and support for students and doctoral students. At specific intervals (1, 3 and 6-year cycles), the board is also to follow-up 1) educational goals, 2) processes for course and programme evaluation, 3) general syllabi and 4) internal evaluation of the subject on the first, second and third cycle. At the school level,

the follow-up mechanisms include course development and course evaluation, as well as the revision of ISPs. Moreover, the doctoral programme is followed up in 3-year cycles.

Procedures for systematic follow-up of doctoral programmes have been established at ORU, and one of the main ways of doing this is through the annual review of the ISP. The ISP is applied for documenting the progress of doctoral education, both from the doctoral student's perspective and from the quality assurance perspective of the school and the subject. With the ISP as a basis, possible challenges at the individual level can be detected and thus, corrective measures can be taken, if needed. In practice, the reasons for any delays/changes are identified through discussion with the doctoral student and the supervisor. Typical reasons for delays are problems with the instruments (i.e. malfunction of a specific research instrument) and/or unsuccessful experiments or difficulties in scheduling courses with experimental work. In more detail, the ISP protocol has the following workflow:

1. A reminder is sent for the doctoral student and their supervisors to update the ISP.
2. In a meeting with the head of school, Head of subject and the study and research administrator, the ISP is discussed in detail, focusing on both the achievements during the previous year (research, publications, courses taken, conference/workshop participation), possible deviations from the plan, activities set for the next year, and the description of the supervision activities. Notes are taken and feedback is sent to the student and their supervisors.
3. An updated version of the ISP is collected and the updates (if any) are checked.
4. If needed, further actions are taken to support the doctoral student: help in better scheduling of experimental work and courses, identification of suitable courses elsewhere, additional supervisors in case there is a need for additional scientific expertise or in some cases, for making arrangements for more time for doctoral studies by additional financing.

The doctoral student has the opportunity to raise quality issues during the annual revision of their ISP (see the following chapter). In support of competence development, there are forums at both the laboratory and division level to exchange experiences and discuss problems related to the supervision, both for doctoral students and the supervisors. The ISP, number of publications, as well as other scientific achievements are followed-up by the faculty. The faculty also supports high-level publications by allocating additional financial support based on the number and quality of the publications.

The faculty board follows up that ISPs have been collected from all students and in case of any unexpected/unexplainable decline in the number of updated ISPs, further action is taken, as described above. In addition, the dean has a discussion with each doctoral student prior to their defence about their research and research education, followed-up by feed-back to the supervisors. The faculty board also recently conducted a survey of the doctoral students' study environment and took action based on the results. For example, the most current survey showed that the majority of the doctoral students (76%) felt that their supervisors were sufficiently involved in their work and most doctoral students felt that they to a high degree have acquired new knowledge. A clear majority (89%) gave doctoral education at ORU the overall assessment good/very good. The areas of concern were the stress experienced by the

doctoral students, more efficient use of the ISP as tool for planning their studies, better information about the rights and obligations of the doctoral students, as well as an improvement of the career support available to doctoral students. The faculty board has already planned the next steps: 1) faculty management will contact the doctoral student section (DokSec) at Örebro Student Union to present the results and anchor the continued process, 2) a more in-depth analysis will be made of the results based on research subject, 3) additional data may be collected from the doctoral students if needed, and 4) those Heads of subject are invited to a dialogue about continued activities based the results of the doctoral student survey.

Doctoral student completion rate

Typically, funding for the doctoral studies is for four years, with possible extension due to e.g. active participation in teaching activities. Over the last five years, the average time for finishing the doctoral programme has been 4.02 years. It should be noted that the externally employed doctoral students typically take longer to complete their doctoral studies, mainly because a majority of them work only part-time with their doctoral studies. Most often, such issues are linked to change of ownership or a restructuring of the company at which they are employed. Majority of the doctoral students finish their studies and there has not been many drop-outs (1 during last five years).

Reflection

We consider that we generally have good protocols for following up the quality of the doctoral programme. However, we are currently developing a more methodological workflow that will allow earlier identification of possible individual challenges, as well as more clear protocols of the corrective measures. For example, an organised schedule for the start-up seminar, half-time control and final seminar prior the defence, However, as the research projects, and thus, the doctoral studies are highly individual, generalised action plans would be not only difficult to develop but also not a best approach for the doctoral students. Here, we will focus on the most typical issues, such as more support needed in academic writing, more individual support in course planning, and more structured instructions for conference presentations. At the faculty level, specific risk areas were identified in the recent doctoral student survey and corrective measures are under development, as described above. The majority of doctoral students finish their studies within the planned timeframe, and all students meet the criteria of four publications/manuscripts. The publications are generally published in high-quality international peer-reviewed journals, demonstrating the good scientific level of the research done by the doctoral students. The quality can always be improved, maybe through more efficient, either internal or external, peer-review procedures, or through the introduction of official mid-way reviews, which we do not currently have.

Doctoral student perspective

To ensure that the doctoral student perspective is taken into account during the doctoral studies, both formally and informally, the faculty has developed protocols for collecting feedback from the doctoral students, for example, by the discussion between the doctoral student and the dean as well as in the form of surveys, as described before. Overall, the university has a policy on student influence and the students have the right to be represented in all preparatory and decision-making bodies. In order to guarantee formal influence, doctoral students have representation on the Faculty Board of Business, Science and Engineering. Doctoral student representatives are appointed by the students' union.

There is a doctoral student section (Doktorandsektionen, DokSek) which is part of Örebro Student Union, and which aims to represent and organise doctoral students at the university level. DokSek organises information seminars and workshops to supplement the formal research education. It also organises social activities to promote networking among doctoral students. These seminars discuss the following subjects: rules and regulations for third-cycle studies, library resources, the writing of grant applications, stress management, thesis production, and research careers within and outside academia.

Doctoral students have the opportunity to raise quality issues during the annual review. The feed-back is an important part of the discussions between the Head of the School and Head of the subject. If needed, action points for improving e.g. the supervision are taken. The head of school organises joint meetings for the doctoral students within the School of Science and Technology, where the students can discuss potential challenges in their studies, and report these to the head of school as well as to the Head of subject. Supervisor meetings at the laboratory and division levels provide opportunities to identify and address potential problems and shortcomings regarding supervision and other elements of the doctoral programmes. For example, the environmental chemistry and metabolomics group arrange weekly meetings to discuss the workflow in the laboratory, plan the use of joint instrumentation and other practical laboratory matters, and these meetings include supervisors, doctoral students, postdoc- and other researchers within the groups. The notes from the meetings are circulated to all members. This allows the group to guarantee equal opportunities for all doctoral students to discuss possible issues within their research, and possible practical equipment problems which are a typical issue within chemistry research, and which may contribute to delays in the research.

Moreover, there are opportunities to discuss the doctoral programme itself. For example, in 2019, the doctoral students were discussing the main challenges and possible delays in their research, high-lighting equipment problems, which may cause major delays in their studies, for instance if specific instruments would break. We have further discussed this in the supervisor group and considered better options for e.g. financing the regular instrument maintenance at the level of the faculty and the unit.

From an individual perspective, the annual update of the ISP, done in a meeting together with the supervisors, gives the doctoral student the possibility to reflect on their doctoral studies and progress. This is naturally also possible during the regular meetings with their supervisors

(typically weekly to bi-monthly). All ISPs are reviewed by the head of school and the Head of subject. At the faculty level, valid ISPs are checked annually. Moreover, the dean meets each doctoral student individually at the end of their studies in order to get feedback from them and to learn from their experiences of the doctoral studies.

Physical and psychosocial work environment

The head of school is responsible for the work environment at the school. The university's website contains comprehensive information on matters of health and safety. The university has a chief security officer and a student safety representative, and at the school there are two local health and safety representatives. In chemistry, laboratory safety is covered on first-cycle courses and study programmes, and for all new recruitments and students, we have an introduction to laboratory safety procedures. We also have annual safety inspection rounds, in which all laboratories are checked for safety. Moreover, we have a designated Laboratory Health and Safety Officer who is responsible for the safety issues at the faculty.

The doctoral students are employed at the university through a doctoral studentship, with the head of division as their immediate manager. The externally employed doctoral students are an exception to this, as they are employed by their respective companies. The head of division and the Head of subject are assigned to assist doctoral students on overall doctoral education matters and to assist the school with the doctoral students. All newly admitted doctoral students, including externally employed doctoral students, are also offered an introduction consisting of two parts. The first part is a local introduction that deals with the division and the school, the subject, supervision and the role of the doctoral student. The head of division is responsible for this. The second part is the university-wide introduction, which contains general information about research, doctoral education and the doctoral student role at the university.

Doctoral students are assigned an office that is typically shared with one other doctoral student. Doctoral students also get a laptop or desktop computer with relevant software, e-mail address, keys and key cards, as well as login information for relevant websites. The allocation of offices and computers is documented in the ISP. The procedure is the same for externally employed doctoral students.

At the Campus Health Centre (which is provided by Feelgood after the university's procurement), there are nurses, midwives, physiotherapists, psychologists and behavioural scientists available for both employees and students. The Campus Health Centre works preventively and with health problems that can arise in connection with work or studies, both physically and mentally. They also offer training to deal with stress and stage fright. At Funka, which is part of the university's Student Services, there are coordinators available to provide support to doctoral students and students with disabilities. DokSek is covering stress management and also organises social activities throughout the year, such as movie nights, bowling evenings and after-work events.

Örebro Student Union has appointed a doctoral student representative to work with legal issues related to doctoral education. Doctoral students who feel that they have been treated unfairly can contact this representative, who has a duty of confidentiality, for help and support. The

representative can assist the doctoral student in various ways in their affairs. Every two years, the students' union compiles a case report that includes those cases that are connected to doctoral studies. In 2019, the faculty conducted a survey for doctoral students and the results were presented to the faculty board, which has already made action points for the identified risk areas. This will also include more accurate identification of risk areas within the different subjects, including in chemistry.

Reflection

ORU conducts employee surveys regularly to follow up on all employees' psychosocial work environment. They include psychosocial indicators/factors such as work hours, fatigue, social climate, feedback and equal treatment. However, this is done at the university level, not at the doctoral student level only. The faculty board also recently conducted a periodic survey of the doctoral students' study environment and took action based on the results.

We have observed that is more challenging to fully integrate the industrial doctoral students in the overall third-cycle programme environment, as they typically perform their studies outside of the university, and often only part time. They do not regularly attend the seminars or discussions arranged at the university, giving thus less opportunities for interactive feedback. Each industrial doctoral student does have a supervisor from the university, and they are followed up by the ISPs, so we do get feedback from them as well. However, we do acknowledge that this is area requiring further development.

Overall, we consider students' opportunities to continuously influence their ongoing education to be good, and they have improved recently through e.g. the joint seminars organised by the head of school. In addition to informal discussions, formal surveys are regularly conducted by the faculty to guarantee that the views of the students are acknowledged, also in anonymised format. Different types of informal student influence are an important complement to the recurring formalised forms of follow-up and participation, and we have several informal systems/groups for this type of interaction. A well-functioning and positive research environment within MTM and Life sciences ensures that the doctoral students can feel comfortable giving feedback also informally. As this is an essential part of the doctoral studies, continuous follow-up of the feedback system is crucial and there is always room for further development. This can be done by improving the information on the different types of interaction and by encouraging the doctoral students to actively give feedback and to also participate at the formal level (e.g. as a representative on the faculty board). Should any challenges in this respect be identified, e.g. as done in the recent survey, practical corrective action is taken.

Working life and collaboration

One of the main goals of doctoral education is to prepare doctoral students for a career both within and beyond academia. Thus, following the public defence, doctoral students should be able to use the knowledge and skills they have obtained through their studies and further build on them during their entire professional lives and in different professional contexts. The most appropriate way to evaluate the applicability of the programme is to follow-up the careers of the doctoral students after the public defence. Of the eleven persons obtaining their doctoral degree in the last five years:

- Three are continuing their research as postdocs at various universities/research institutes (ORU, Novo Nordisk Foundation Center, National Hellenic Research Foundation)
- Two are working at another institute (UNITAR, UN Institute for training and research, Division Planet, Chemicals and Waste, Geneva; Arbets- och miljömedicin, Örebro)
- Six are working in industry/private sector (Wellington, Waters, Structor, Orica, Knoell)

A majority of the doctoral students find a position quickly after the public defence, thus demonstrating that the skills developed during their doctoral studies are sought after in industry and academia. A number of factors contribute to the employability of the doctoral students. Due to the multidisciplinary nature of the research done in chemistry at ORU, including the collaborative projects with both academia and industry, the doctoral students have several opportunities for future employment after the public defence. Due to the extensive network at MTM, the doctoral students have good opportunities to create contacts themselves. In addition, the principal supervisors - who all have good networks - are well-placed to prepare the doctoral student for a career both within and outside of academia. Moreover, the doctoral studies are typically conducted in projects, often in collaboration with other research groups and often also with industrial partners, which contributes to the doctoral students developing a research network already during the doctoral programme. Such networking is encouraged at the university level through financial support to participate in conferences and workshops.

Through close collaboration with industrial partners, we also get continuous feedback on our doctoral programme, a better understanding of the needs of the industry related to the doctoral programme, and information on the skills required by the young PhDs in industry. Furthermore, some doctoral students are externally employed doctoral students, which means that they already have an employment and career outside academia. In chemistry, the majority of projects include a large amount of practical laboratory work, data analysis, writing and presentation, thus providing competence in various areas of research. Particularly, the technical skills developed during the doctoral studies are typically applicable to a broad range of different disciplines, as the same instrumental techniques within analytical chemistry can be used for very different applications. For example, chromatographic and mass spectrometric techniques applied in e.g. environmental analysis are highly similar to those used in e.g. biochemical analyses or food analyses. In addition, both doctoral courses and the doctoral

studies as such contribute to developing skills such as project planning, problem solving and management, which prepares the doctoral student for project work and project management both in academic research and in industry.

The doctoral students have also an opportunity to take part on departmental duties such as teaching, organization of workshops and conferences to support their future career. A majority of the doctoral students (excluding industrial students) participate in teaching, and many doctoral students have participated on organising workshops and conferences. For example, MTM recently organised an International Symposium on Polycyclic Aromatic Compounds (ISPAC, September 9-12, 2019), and several PhD students participated on the organisation of it.

Reflection

Overall, based on the measurable parameters, such as the number of doctoral students employed after the public defence, we consider that our doctoral programme meets the expectations from a career viewpoint. This is also supported by the recent doctoral survey that showed that majority of the doctoral students are not worried about employment prospects, however, they would like to get better support for career planning. The latter is currently under development. Evaluating the current positions of previous students shows that they have been employed by academia, other research institutes, as well as in industry. This shows that the doctoral programme can meet the demand in a wide range of areas. However, it is crucial that the demands from a world-of-work perspective are continuously followed. As discussed above, this is also due to the nature of the research discipline that has a strong focus on instrumental methods, in addition to basic research skills, which is widely applicable in different areas of working life. We consider the wide applicability of our doctoral programme to be crucial, as this also attracts new doctoral students to our group. Therefore, continuous evaluation and development in this area is important. We have identified one specific area of improvement: we need to take better advantage of the opportunities to use feedback from and the experiences of our alumni, both with regards to their experiences of their doctoral studies and of their professional life. We have already invited our alumni to give seminar presentations at ORU, as part of a whole day seminar organised in 2019, however, we do not yet have a formal system for this. We are currently discussing at the division level the best approaches for this, including a more systematic way of getting feedback from industry and the public sector. This feedback could then be used when planning the programme and the courses. However, it should also be emphasized that the requirements from the world of work, while they are important and should be reflected in the programme, should not be the guiding principles for the intended learning outcomes of the academic doctoral degree.