A roadmap for developing permafrost higher education in Norden

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Abstract The increasing need for and use of permafrost knowledge in Arctic societies--undergoing climatic changes with different challenges caused by thawing permafrost--calls for an understanding of the state of permafrost higher education offered in the Nordic area. Until now no curriculum mapping of permafrost higher education has been done. Therefore, it is important to establish an overview of the student experiences that form the permafrost educational process within higher education in the Nordic area--a culturally distinctive region that covers the full diversity of permafrost types. This has now been done by surveying based on detailed questions at institutional level, study levels and which teaching forms are presently forming the Nordic permafrost study offer. As part of this investigation, we have also mapped plans for future development to be able to address how to improve permafrost education. The results from this first Nordic permafrost curriculum mapping, performed at 11 universities representing all Nordic countries, show that permafrost is taught within both bio-and geosciences and engineering, and that there is variation in educational activities. Only five permafrost-specific geoscience and engineering permafrost courses are offered in Norden, whereas there are 23 bachelor and 25 master courses with a permafrost content ranging from 1% to 50 %. Presently, there is no specific course offer at PhD level on permafrost in Norden. The curriculum mapping establishes a first roadmap overviewing all permafrost educational activities in Norden.

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The overall outcome of our survey shows large potential for increased and deeper inter-university collaboration for further developing joint permafrost higher education in the form of courses and with ambitions for joint permafrost degrees between several institutions. Based on the presented results and the mapped different future plans for permafrost education across Norden, we discuss the implications of our results, specifically concerning the potential for increased collaboration in Nordic permafrost education. These focus on permafrost course development, teaching methods, sharing practical experiences including fieldwork and further developing the educational offer. In more detail increased collaboration could establish: 1) An online, joint Nordic-specific course on permafrost, sharing the special permafrost competences existing across the universities using digital teaching tools, 2) Nordic collaboration on developing joint PhD courses on permafrost, 3) Lifelong education in permafrost, and 4) Internships as part of active permafrost education to better meet the needs of future employers and society. The Nordic region might also gain largely from establishing an interdisciplinary joint Nordic course, aiming to characterize the region and its diversity broadly and including both natural and social sciences, and naturally covering different topics including permafrost and seasonally frozen ground.

1 Introduction

The present climatic changes cause an increasing focus on how the cryosphere is reacting, primarily in Arctic areas, where the largest climatic changes are occurring (Rantanen, et al., 2022; Constable et al., 2022). Permafrost forms an important part of the cryosphere. It occurs in 15% of the exposed land surface area in the Northern Hemisphere (Obu, 2021), but is more widespread in the Arctic area (Figure 1). Permafrost is warming most in the continuous permafrost areas of the high Arctic on average 0.4°C/decade (2007-2016) following the Arctic amplification of air temperatures in the Northern Hemisphere (Biskaborn et al., 2019).

Permafrost investigations have primarily focused on 1) the contribution of greenhouse gases (GHG) to the atmosphere as a result of on-going warming, 2) engineering challenges, and 3) basic research in geomorphology / planetary sciences (Sjöberg et al. 2020). However, recent studies also point clearly to the effects of increased permafrost thawing, and in particular the direct effects on societies (Constable et al., 2022). The extensive use of permafrost knowledge in society led us to investigate the status of permafrost education at the Nordic universities and based on our findings, to discuss and identify future useful and necessary developments.

Our main research objective is to survey the permafrost curriculum to map the totality of student experiences that forms the permafrost educational process within higher education in the Nordic area. To do so we study 1) which study levels and 2) which teaching forms (including active learning) are included. Only this way are we able to characterize the present overall Nordic permafrost curriculum offer and based on these findings, discuss future permafrost higher education within the context of the large focus presently placed on permafrost motivated by the ongoing climatic changes. We

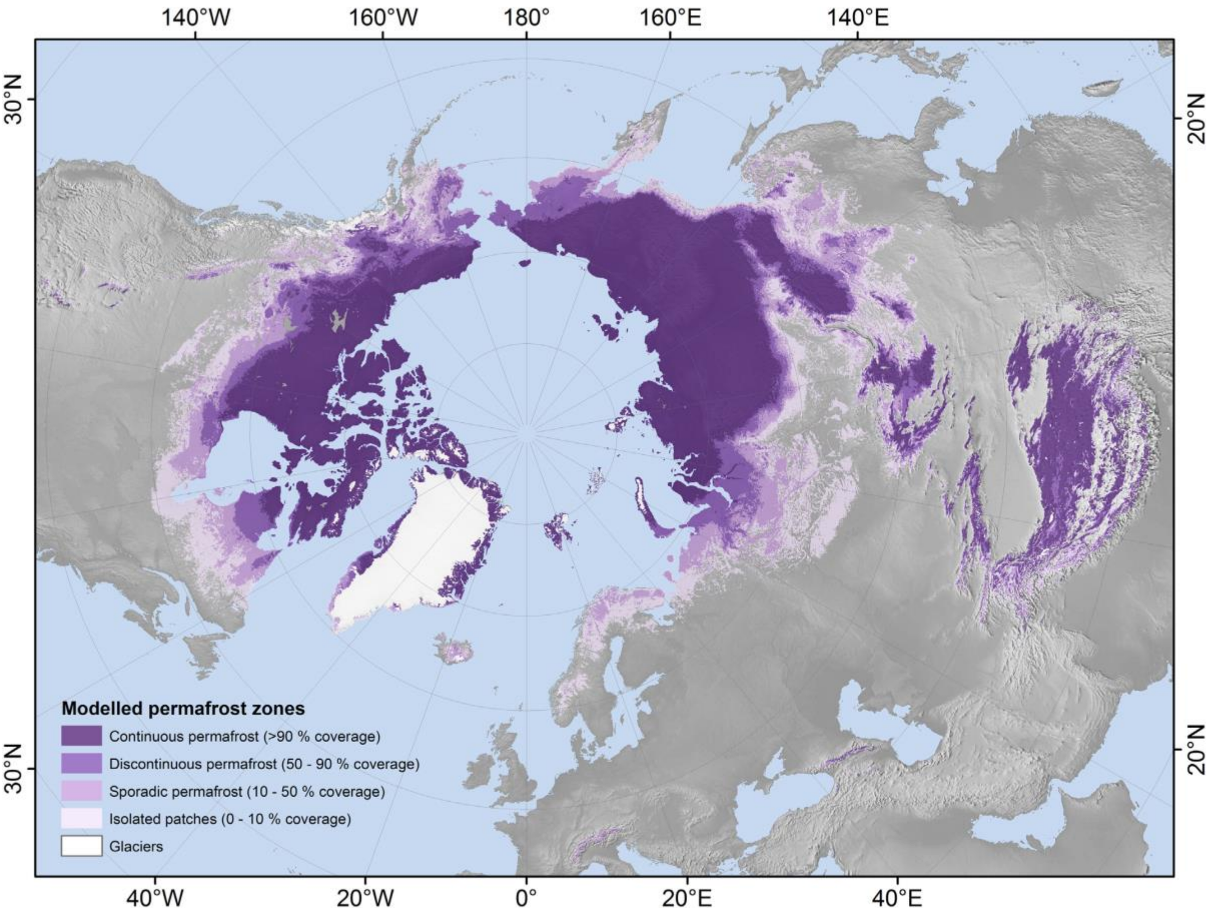

***Figure 1**. Most recent map of permafrost areas in the Northern Hemisphere. The distribution of the permafrost zones is based on modelled permafrost probabilities, from Obu et al. (2019).*

emphasise a need for such a study to enable discussing to which degree the present state of Nordic permafrost education can meet the expectations of future research needs and employers, and to evaluate how we can identify ways to improve the present permafrost education across the Nordic area.

Norden is defined as the Nordic area of Denmark, Finland, Iceland, Norway and Sweden, together with the three autonomous territories connected to these states: the Faroe Islands and Greenland (Denmark) and Åland (Finland). This region contains the largest climatic gradient in the Arctic, between very cold northern Greenland and relatively warm Svalbard and Fennoscandia. The region consequently also has a unique gradient from continuous to sporadic permafrost (Fig. 1). Thus, the setting is ideal for permafrost education by covering many aspects of permafrost science and engineering highly relevant for the Nordic societies.

In addition, the Nordic states are widely considered to form a distinctive region by virtue of their strong historical ties and the tradition of inter-governmental co-operation across national boundaries. The Nordic region is also relatively small, and the mutually intelligible languages of Sweden, Norway, Denmark and Finland allows possibilities for easy cultural cooperation, and communication, supplemented by extensive use of English as an instructional language in universities.

Presently, permafrost is studied as part of many STEM disciplines, from engineering to ecosystems. Permafrost basics is typically taught mainly in geoscience and engineering educations. Permafrost is even part of research outside the STEM area, such as within medicine and social science, but here we focus only on the STEM fields, to evaluate permafrost education within STEM faculties across the Nordic area.

With the increased pertinence of permafrost-related knowledge to many different disciplines, unfortunately the use of basic permafrost science is sometimes challenged due to the lack of simple physical permafrost background knowledge. There are examples of high-profile scientific publications that do not use well-established definitions and scientifically justified basic permafrost terminology (e.g., not separating the active layer from the permafrost), or do not have any background information on landform site selection, both of which can affect the results of scientific research. There is therefore a need for basic, modern permafrost education to be readily available as part of university education across the extent of disciplines that do research involving permafrost.

2 Background

Here we review the status of collaboration on permafrost higher education in the Nordic area with a focus on the types of activities up until now.

A Thematic Network on Permafrost (TNP) was established in 2013 as part of the University of the Arctic (UArctic), with the primary goal to establish, sustain and strengthen a network of university institutions that give permafrost research-based education primarily between UArctic members, and with some non-UArctic partners. The TNP has been coordinated jointly with the International Permafrost Association's (IPA) Standing Committee on Education and Outreach. TNP promotes research, education collaboration and joint projects in permafrost, its impact on environment and adaptation to climate change. The main form of cooperation is joint research and education projects such as summer schools, ambitions to develop joint Master/PhD programmes, as well as knowledge sharing aimed at addressing, in a multidisciplinary way, the contemporary issues in the field of cryosphere focusing on permafrost in the northern regions. We use the survey data collected for this work to study to which degree the TNP has been successful in the Nordic area, and based on this, we discuss future ideas for joint collaborative permafrost education across the Nordic area.

The few available publications on permafrost education typically relate to how to involve teachers and high school students in permafrost research (Klene et al., 2002). More papers focus on the development of educational tools using new media and technology (e.g., Nitze et al., 2021), but do not typically evaluate these tools in educational settings. And this work is typically published in disciplinary journals, to attract attention from specific disciplinary users. The Frozen-Ground cartoons project makes permafrost accessible to school children, teachers, and the public (Bouchard et al., 2019, Bouchard et al., 2022; https://frozengroundcartoon.com/cartoons/). The cartoons are translated in Danish, Swedish and Greenlandic, as well as six non-Nordic languages.

The Permafrost Young Researchers Network (PYRN) also focuses on permafrost education. It is a legacy of the International Polar Year (IPY) 2007–2008, initially an IPY outreach and education activity by the IPA, which was started in 2005 (Tanski, et al., 2019). PYRN has developed into an active network that connects young permafrost scientists, engineers, and researchers from other disciplines. PYRN focuses on improving international and interdisciplinary exchange between young researchers. There has been some national PYRN activities in the Nordic area and Nordic involvement in the leadership of PYRN.

2.1 The history of Nordic permafrost collaboration

There is presently no current overview of the permafrost education in the Nordic area. The only overview was obtained following the IPY 2007-2009 period, when the permafrost course activity was first surveyed and presented in the online *International Database on University Courses on Permafrost* (IUCP) educational service. This service was developed as part of the IPA's IPY activities (Christiansen et al., 2007). The goal of the overview was to include all available university- level permafrost courses during the IPY period 2007 to 2009 dealing with permafrost and periglacial geomorphology, for both science and engineering, and in both hemispheres. As a result, it was recognized that relatively few dedicated permafrost courses existed at a university level, and that an important part of the IPA-IPY legacy would be to foster the development of the next generation of permafrost researchers. The IUCP had details of all courses provided by the 26 IPA member countries and coordinated by the IPA Secretariat. The IUCP was annually updated by the TNP for several years following the IPY, and it was viewed as an essential tool for students interested in studying permafrost to gain an overview on the permafrost courses offered (Christiansen et al., 2007).

In preparation for the IPY, a planning meeting was held in 2006 in Svalbard, gathering permafrost scientists working in the high Arctic from Canada, Denmark/Greenland, Japan, Norway, UK, and USA. They investigated if a high Arctic permafrost course could make use of the northernmost terrestrial transect from Ellesmere Island, northernmost Canada, over Peary Land in northernmost Greenland to Svalbard. It was one of the IPY ambitions at that time, i.e., to establish logistical links across the high Arctic in this region. Unfortunately, this rather challenging ambition failed due to missing logistical coordination between the countries in question.

But by using Norwegian IPY funding in the *Thermal State of Permafrost in Norway and Svalbard* (TSP Norway) project along with support from the University Centre in Svalbard (UNIS) and the Nordic Arctic Cooperation program (2006-2008), it became possible to plan and run a joint master course in 2008 between UNIS and the University of Copenhagen (KU). It was called AG-333 'International Research Course on High Arctic Permafrost Landscape Dynamics in Svalbard and Greenland'. This course was established as a course at UNIS providing credits to the ten attending graduate students. The main aim was to provide a multi-disciplinary field-training experience for internationally recruited graduate students dealing with the dynamics of high arctic terrestrial permafrost and its soil environments during IPY. More specifically it focused on combining research and educational investigations of high Arctic landscape variability across the steepest high Arctic climatic gradient from maritime Svalbard (78°N) to continental NE Greenland at Zackenberg (74°30'N) by doing a fieldwork permafrost project. Several of the participating students today work with permafrost science or related science topics in Nordic universities or institutes, and the collected permafrost material was used for scientific publications such as Elberling et al. (2010)

and Christiansen et al. (2010). Besides this permafrost focused course, a general Arctic bachelor-level summer research school with a strong permafrost component was held as part of the IPY in 2009 on Svalbard.

Following the IPY Nordic permafrost collaboration continued in the form of two smaller Nordic Arctic cooperation projects over the period 2009-2014. First the *Permafrost Observatory in the Nordic Arctic: sensitivity and feedback mechanisms of permafrost changes* (NORDIC-PERM) ran between 2009 and 2011. It focused on Nordic collaboration within physical and biogeochemical permafrost observations based on the different IPY permafrost project activities in the Nordic area. This project was led by University of Copenhagen with UNIS, Stockholm University, University of Oulu and Bioforsk, Norway as partners. There were no direct educational components in this project, which instead focused on direct scientific collaboration. Moreover, this new biogeochemical collaboration led to joint participation in the following EU projects.

From 2011 to 2014 the *PERMA-NORnet* Nordic researcher network project focused on a broader collaboration between seven permafrost research groups at the universities of Oslo, Copenhagen, Stockholm, Oulu, Helsinki, UNIS, the Norwegian Meteorological Institute and the Danish Meteorological Institute. The project was led by Oslo University and focused on workshops and PhD courses with a strong emphasis on research-based education to establish cooperation between the thermal, biogeochemical and hydrological processes affecting permafrost. A joint PhD and advanced master level permafrost modelling course was held in Oslo in 2012, and a field-based high Arctic permafrost landscape dynamics course in Svalbard and Greenland was held at Zackenberg research station, NE Greenland in 2013. Moreover, a joint PhD and advanced master level course on low Arctic permafrost and periglacial processes was held in northern Norway and at the Kilpisjärvi (Finland) research station in 2014. In addition to excursions, the course included fieldwork (e.g., geophysical survey of a palsa, a sporadic permafrost landform in a mire environment), seminars and computer labs (geospatial data-based statistical modelling of permafrost landforms).

This collaboration project with its different workshops and PhD courses clearly led to increased Nordic collaboration both for PhD students, but also for scientists. When the Center for Permafrost was established at Copenhagen University in 2012, two staff members from two Norwegian permafrost research groups worked in 20% positions in this center, just as UNIS has had the later leader of the Center for Permafrost appointed into a 20% position. Increased collaboration on PhD supervision, typically between two different Nordic institutions, also took place as a direct outcome of this collaboration. Several scientific publications are the clear legacy of this collaboration, many publications first-authored by PhD students such as, e.g., on the establishment of a Nordic permafrost map (Gisnås et al., 2017), geomorphological and cryostratigraphical studies from Zackenberg, NE Greenland (Cable et al., 2018), landform partitioning and storage of soil organic matter in Zackenberg (Palmtag et al., 2018), cryostratigraphy, sedimentology and late Quaternary evolution of the Zackenberg Delta (Gilbert et al., 2017), and modelling present and future permafrost thermal regimes in Northeast Greenland (Rasmussen et al., 2018). A joint overview of the permafrost thermal state during the International Polar Year (IPY) was developed and published (Christiansen et al., 2010), also building largely on this network.

A broader engineering-specific Nordic educational collaboration accommodated higher education on permafrost. In 2016, the Nordic Master in Cold Climate Engineering

(CCE) was established as a joint master programme between the Norwegian University of Science and Technology (NTNU, Norway), Aalto University (Finland), and the Technical University of Denmark (DTU, Denmark). This master programme is a 2-year double degree programme, where students benefit from spending one year at two of the three involved institutions and obtaining a final diploma from both of those institutions. Especially the “land track” of the CCE programme has a strong focus on permafrost-related issues in engineering, giving students the opportunity to experience permafrost and the related engineering issues first-hand, through studies at the Arctic DTU campus Sisimiut (Greenland) and at UNIS (Svalbard). Besides the regular courses taught at these institutions, the students also can do the master thesis focusing on permafrost-related engineering issues.

Despite the above activities, to our knowledge there has not been a general overview of Nordic permafrost higher education efforts thus far. Therefore, there is a need for performing an overall survey, mapping the higher permafrost education. Also, outside Norden there are no permafrost curriculum surveys done that we know of. Most likely this is due to permafrost being a much smaller topic than most other science topics taught at university such as, e.g., chemistry. For chemistry, curriculum surveys have been done even at individual study levels and through time, such as most recently presented by the undergraduate analytical chemistry curriculum survey by Kovarik et al. (2022).

3 Methods

During an online meeting, to which all Nordic permafrost scientists and engineers at universities were invited in spring 2022, the content of a first permafrost curriculum survey was discussed using the experience from across Norden to develop the survey to map all types of permafrost higher educational activities and future planning in the region. The survey was developed to focus on obtaining a detailed, strictly factual mapping of which types of permafrost education is presently offered within Nordic STEM faculties, and also collected information on plans or ideas for how to develop permafrost higher education. The survey thus included detailed questions about which university levels permafrost science and engineering are taught in, whether specific permafrost courses are offered, and to which degree permafrost is part of other types of courses. We mapped in which disciplinary contexts permafrost is taught and requested information about field and laboratory components in courses to access the active teaching level, and whether thesis work on permafrost is possible. The survey also registered the duration that the involved permafrost educators have been teaching permafrost at university level. Finally, the survey asked for reflections on how the future permafrost education was planned to or should develop, and if the respondents saw any need for joint Nordic permafrost educational collaboration, and if so, in which way.

When mapping field and other practical, directly active educational components such as laboratory work, the survey included which type of activities existed. This was split into field excursions lecturer-led, fieldwork lecturer- or student-led, and how much time these components were each estimated to be. As only two institutions differentiated in lecturer- and student-led activities, this differentiation is not included in this survey.

The survey of the information about all basic aspects of permafrost higher education was answered by the authors of this paper, who almost all joined or expressed interest in the Nordic permafrost educators online meeting that designed the survey. This meant that for each institution, one staff member has coordinated the replies from several colleagues across departments. For Umeå University, three staff members each answered the survey. We do not think this approach poses any threat to the validity of the mapping, when the mapping is basically a collection of the factual amount and types of permafrost education. Rather we see the value in having the permafrost lecturers across Norden, as those who know best which educational permafrost activities are going on, answer the survey and also ensure that input from colleagues across their institutions, also teaching topics with some permafrost content, were included. Finally, as the number of staff that are involved in permafrost higher education in Norden is rather limited, the relatively large author group represents almost all known permafrost educators in Norden. It has therefore not been possible to have the collected information analysed by other, independent, permafrost educators.

4 Results

Eleven universities contributed information to this survey from all the Nordic countries. Three in Norway: University of Oslo (UiO), The Norwegian University of Science and Technology (NTNU) and the University Centre in Svalbard (UNIS), three in Sweden: Stockholm University (SU), Uppsala University (UU) and Umeå University (UMU), two in Denmark: the University of Copenhagen (KU) and the Technical University of Denmark (DTU) with its Arctic DTU campus in Sisimiut, Greenland, two in Finland: University of Oulu (UoO) and University of Helsinki (UH) and one in Iceland: University of Iceland (UI). Permafrost is also taught as part of educational activities in some other universities in the Nordic area, but since there has not been any direct membership in the TNP nor any other known specific permafrost educational activities, we expect the selection represents the main permafrost higher education offerings in the Nordic countries.

4.1. The level and type of permafrost higher education

Surveying the number of specific permafrost courses - that is, courses with a major permafrost content and which typically had permafrost in the title of the course – showed that nine of the eleven participating universities did not report any specific permafrost courses. SU and UNIS offer in total five specific permafrost courses (Table 1 & Supplementary Table A). At SU the 7.5 ECTS 'Permafrost – Interactions with ecosystems and hydrology' course (GE7051) is offered at master level and is a part of the master's programme in Polar Landscapes and Quaternary Climate. The course was started in 2013, since permafrost-related research has been prominent at the Department of Physical Geography since the mid 2000's. Most years the course has had around 10-15 students, but it can take up to 18. The majority of the students are international students taking the full master's programme, but students from other master's programmes at SU, or from any other institutions, can also apply to take the course. The course is also open to PhD students, if they fulfil the prerequisites.

At UNIS there is one 10 ECTS course offered at both master and PhD level: AG-330/AG-830 'Permafrost and Periglacial Environments', and two 10 ECTS master-level courses: AT-329 'Cold Region Field Investigations' and AG-352 'Geohazards and Geotechnics of high Arctic permafrost regions', and one bachelor 10 ECTS course: AG-218 International

Permafrost Bachelor Summer Field School. All these courses can take up to 20 students as a maximum due to the practical field and laboratory parts of the courses. The AG-330/830 course, developed from a former master course in glacial and periglacial geomorphology in 2005, was first run in 2007. Norwegian UArctic funding allowed permafrost summer field schools for bachelor students to run in 2014 and 2015 at UNIS in close collaboration with international colleagues, and since then UNIS has included the AG-218 course into its curriculum, providing a general bachelor-level course, introducing students to the various aspects of permafrost research and engineering. The AG-352 course was developed with INTPART funding from the Norwegian Research Council in 2019 as part of a research and higher educational exchange programme between Norway, Svalbard and Canada. Due to Covid-19 the first operation of this course was delayed 2 years. It was run in 2022 for the first time. The AT-329 course has been revised over the last years to now focus mainly on permafrost. All four UNIS courses typically experience a high number of applicants for each course, and there is usually a waiting list of students hoping to attend these courses. However, so far UNIS has not been able to run all four courses during one study year. This is partly due to Covid-19, but also due to staff capacity and financial issues.

By far, most Nordic permafrost higher education seems to take place in courses where permafrost is not the main focus, but rather plays a minor role (Table 2 and Supplementary Table A). This is the case both at bachelor and master level, whereas there is only one such PhD-level course in this survey. The survey contains 23 bachelor courses and 25 master-level courses directly identified as having some permafrost content. For the bachelor courses from *c.* 5 to 50%, but typically 5-15% of the content is about permafrost (Figure 2). For the master courses the permafrost content is somewhat higher from 10 to 40% (Figure 2). Some of these courses are short field courses, typically 2.5 or 5 ECTS.

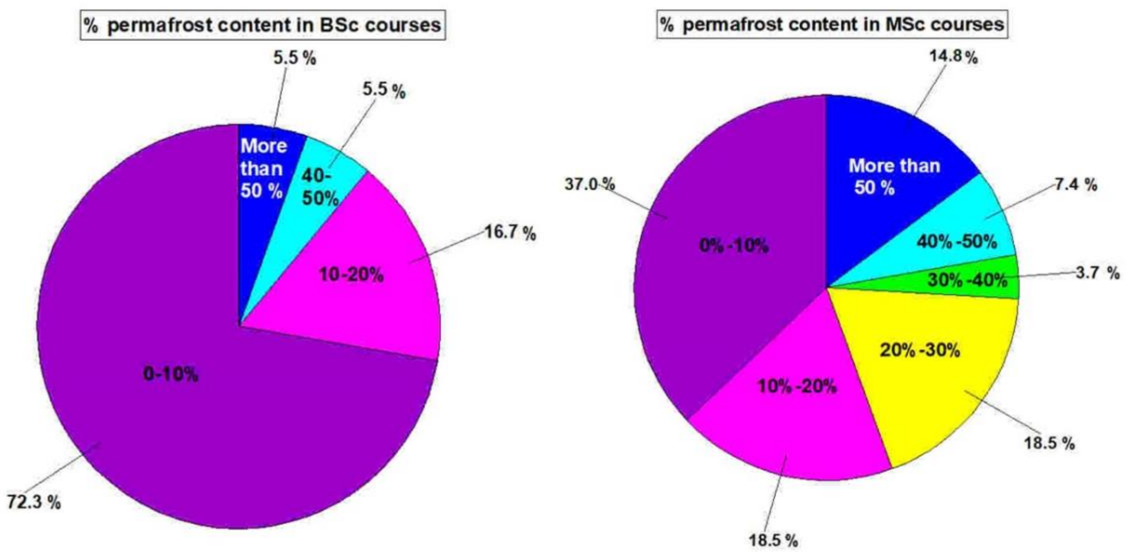

Figure 2. *Distribution of the permafrost content (%) in all the mapped bachelor and master courses, based on data from Table 1 and Table 2. All permafrost-specific courses form the category > 50% for both bachelor and master courses.*

Eight of the nine surveyed universities offer both bachelor and master theses within permafrost topics, both within geo- and bioscience and engineering. Also, some PhD theses supervision within permafrost topics takes place.

The main disciplinary contexts that permafrost is taught in are physical geography, ecology, environmental science, and engineering. Permafrost is mainly included in physical geography/geoscience introduction courses at both bachelor and master level, but also in some general geomorphological courses, in some biological ecosystem courses, and in the field and methods courses in geoscience and engineering. Finally, permafrost is included in construction and infrastructure civil engineering courses.

Most of the participating science institutions identify their main aim for students to understand the role of permafrost in the global biogeochemical cycle as their overall permafrost educational aim. Others aim for students to understand the role of periglacial processes (incl. permafrost) in landscape development, pre-Holocene and Holocene permafrost reconstructions, permafrost in natural hazards, biogeography, ecology, climate change, permafrost in climate models, remote sensing of permafrost and sustainable development of the Arctic as their main educational aim. For the participating engineering institutions/departments they aim for students to understand the principles of interaction between permafrost and built structures, and the risks involved in construction on degrading permafrost.

Historically, permafrost issues have been taught in the context of geotechnical engineering as part of the education since 2001 at DTU (course 11801 Geologi og Geoteknik), but the education was restructured into the current CDIO (Conceive, Design, Implement, Operate) based course structure in 2007, with the permafrost content distributed among the two current courses included in this survey (Table 2). The third course (12854 Arctic Infrastructure Constructions) with permafrost related content, given at Arctic DTU Campus Sisimiut, was developed in connection with the establishment of the Nordic Master in Cold Climate Engineering, and is offered to international students as part of an Arctic Semester in Sisimiut, Greenland. It is based on the same principles of student engagement and active, problem-based learning with a focus on an engineering context, rather than the classic topic-based university teaching. Arctic DTU Campus Sisimiut courses have a maximum of 15-25 students on courses with permafrost relevant teaching elements, due to field and laboratory activities. Student uptake is relatively constant, and typically the courses are not full. This may be because students must engage in the full professional bachelor education or a full semester of master courses to participate.

The presented mapping shows that the International University Courses in Permafrost (IUCP) IPY online service (Christiansen et al., 2007) is still in demand, but it has, unfortunately, not been maintained in recent years mainly due to lack of resources and challenges with reaching prospective students. For most courses in the IUCP, it was possible to directly access course information in English on the host university webpage. In 2007 there were 136 courses listed in 17 countries. Most courses were taught at institutions located outside permafrost regions, but several (mainly field courses) were offered within permafrost regions, mostly in Russia, Alaska, and Svalbard. The web presentation and search tools allowed easy access to the information about each course and created a previously unobtainable global overview. There were 22 courses in Norway, five in Sweden, and one in Denmark (none in Finland and Iceland) included in the IUCP in 2007. Based on the present mapping this shows that almost all these courses have had little permafrost content. And we show an increase in the number of partial or full permafrost courses to 53.

4.2 Field and laboratory activities in the permafrost training

In permafrost higher education the most important active learning components are typically fieldwork and associated laboratory work. Only one of the participating universities does not offer any field activity, but some computer labs, whereas all other institutions offer both field and laboratory activities in all types of their permafrost education (Table 1 and Table 2). In the five permafrost-specific courses, the field and practical components range from 20 to 50%, ensuring large active learning parts. For the courses with permafrost included but not dominant, the field and practical components are typically lower, but ranging up to 70%. Several institutions have in these partial-permafrost courses up to 50% practical computer-laboratory work, whereas this is not the case in the permafrost-specific courses.

Most of the field activities (Figure 3) are in the form of a concentrated field excursion and/or field components taking place during one field visit away from campus to field stations. Many institutions include computer-laboratory work into these courses, and include up to 40-50% at two institutions. Importantly, most mapped permafrost education has a rather high active learning component, with students actively doing observations themselves.

Table 1. *Information on the specific permafrost courses. Those are the courses with a major permafrost content, and which typically had permafrost in the title of the course.*

Institution	No. BSc courses, no. of course ECTS, field and laboratory components %	No. MSc courses, no. of course ECTS, field and laboratory components %
SU		**1**, 7.5 ECTS, practical components 40% (also open to PhD students).
UNIS	**1**, 10 ECTS, 30% excursions and fieldwork 30%, lab work 5%	**1**, 10 ECTS, excursions/fieldwork 10%, lab work 10 % (also PhD level) **1**, 10 ECTS, excursions/fieldwork 35-40%, lab work 10% **1**, 10 ECTS, fieldwork 20%, lab work 15%

Table 2. *Information on courses with permafrost included, but not as a dominant component.*

Institution	No. BSc courses, %permafrost in course, no. of course ECTS, field and laboratory components %	No. MSc courses, %permafrost in course, no. of course ECTS, field and laboratory components %
UoO	**2**, 5%, 5 ECTS	**1**, 15%, 5 ECTS **1**, 40%, 5 ECTS, fieldwork 70%
SU	**1**, 20 %, 2.5 ECTS, **1,** 6 %, 15 ECTS **1,** 2 %, 15 ECTS **1,** 2 %, 10 ECTS **1,** 2%, 15 ECTS **1,** 1 %, 30 ECTS	**1**, 20 %, 15 ECTS, excursion 30%
UU	**2**, <5%, in total 40 ECTS, practical computer labs 20%	**2**, 10%, in total 25 ECTS, practical computer labs, 10%
UMU	**2**, 7 hours, 15 ECTS, have field components	**1**, significant parts on pf, 15 ECTS, field components majority of course
KU	**3**, < 2%, in total 22.5 ECTS	**1**, 15-30%, 15 ECTS, 10 days fieldwork < 50% permafrost focus **1**, 10%, 7.5 ECTS, practical computer labs **1**, 5-10%, 7.5 ECTS, practical computer labs **1**, 12.5%, 7.5 ECTS, practical computer labs. **1**, variable %, 7.5 ECTS **2**, < 5%, in total 22.5 ECTS, practical computer lab
DTU	**1**, 15%, 12.5 ECTS, field component 12 %, lab 10% **1**, 5-10%, 10 ECTS	**1**, 30%, 15 ECTS, fieldwork 5%, labwork 5-10%, computerlab 5-10%
UiO	**1**, 15-20%, 10 ECTS, 2 hours weekly computer lab	**1**, 30%, 10 ECTS, field + computer lab components **1**, 10%, 10 ECTS, 3-day field excursion, 50 % computer lab
NTNU		**1**, 5%, 7.5 ETCS, 3 hours self-learning online module **1**, 25%, 15 ETS **1**, 30%, 7.5 ETS, field + laboratory components
UNIS	**2**, 10%, 15 ECTS, fieldwork 2-5%, lab 5% **1**, 50%, 15 ECTS, 50%, fieldwork 5%, lab 5 %	**1**, 50%, 10 ECTS (also at PhD level), fieldwork 10%
UI	**2,** <5%, 10 ECTS, 5-day field excursion (not fieldwork)	**1,** <5%, 10 ECTS (mixed MSc & BS), 5-day field excursion (not fieldwork)
UH		**1**, 50 %, 8 ECTS **1**, 20 %, 3 ECTS **1**, 20%, 5 ECTS **1,** 10%, 5 ECTS

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Figure 3. *Students actively learning permafrost in the field in Norden. A) Studying initial rocksliding in the Kilpisjärvi region, N Finland (photo: Jan Hjort); B) Studying a palsa in Tavvavuoma, N Sweden (photo: Britta Sannel),; C) A student doing GPS of a resistivity line in the Sisimiut area, Greenland (photo: Sona Tomaskovicova); D) Students doing permafrost coring in Adventdalen, Svalbard (photo: Hanne H. Christiansen); E) Students visiting the Solheimajökull, Iceland discussing glacial and periglacial processes and permafrost and slope stability (Photo: Olafur Ingolfsson); & F) Students mapping the active layer and doing soil characterisation in the Sisimiut area, Greenland (photo: Sona Tomaskovicova).*

4.3 Experience of teaching permafrost at university level

We mapped how long the survey participants and their institutional colleagues have been teaching permafrost at the university level. Replies include both the length of the permafrost or periglacial geomorphology course offering, typically focusing on how long the specific permafrost courses have existed, in addition to the time the individual scientists and engineers have been teaching permafrost courses. The Nordic permafrost teaching team consists of professors who have been teaching for up to 32 years at university level, as well as young assistant professors, who started teaching one year ago. All the countries surveyed have teaching staff that includes assistant professors to full professors, and several institutions have two-to-four staff members involved in permafrost education.

4.4 Reflections on developing permafrost education at university level

Not all participating institutions have addressed how to develop permafrost education, and among those that have, the replies vary. There is a wish to see permafrost content integrated into different courses in environmental sciences. Wishes to generally strengthen permafrost education include more practical field and laboratory work, and the development of more permafrost-specific courses. Others want to focus on shifts in long-term climate impacts, and some want to focus on tight integration between field observations, numerical modelling, and remote sensing. There is a suggestion for lifelong education/further education for professionals within permafrost engineering to improve managing the effects of the ongoing ground warming and associated changes in the built infrastructure. Finally, some suggest the development of internships to improve the interaction between future employers of permafrost students and universities.

4.5 Need for closer Nordic collaboration on developing the permafrost educational offer

There is very clear general agreement that it would be beneficial to further develop closer Nordic collaboration within permafrost higher education. Developing Nordic collaboration is seen as obvious by several respondents, as the Nordic area contains a natural gradient allowing for studying all the different permafrost zones across this region in combination with seasonal frost. A clear suggestion is for joint courses, as well as field courses. Closer collaboration is also seen as a way to share special permafrost competences across the universities. This is even easier now that digital teaching has become more common. A joint Nordic online course that covers different topics of permafrost is mentioned. But also, joint high level specific PhD courses focusing on different parts of permafrost studies such as modelling, remote sensing of permafrost, periglacial geomorphology including coastal dynamics, permafrost in geohazards, within engineering topics and ecology – greenhouse gasses are suggested. Finally, a joint system for permafrost internships is suggested.

Specifically, staff at both engineering institutions point out that there is a need for more general permafrost knowledge as part of the basic education to avoid potential critical conditions (e.g., ground thawing due to missing understanding when constructing), to allow for safe and sustainable engineering practice and to ensure using the right information and guidelines when constructing on permafrost.

Several mention the need for having an overview/catalogue/a coordinated place where both students and staff can see what projects, internships and courses are available within permafrost education. This resource could also allow staff to get inspiration and potentially share practical experiences, including specific exercises that provide inspiration for teaching about permafrost in the classroom and in the field.

5 Discussion

5.1 Permafrost higher education

Our fact-based survey allows further developing permafrost higher education, as has been successfully done for other scientific fields (Uchiyama & Radin, 2009), increasing closer collegial collaboration. The presented mapping allows permafrost educators a shared understanding of the present situation by sharing, discussing, analyzing and potentially realigning/further developing the permafrost higher educational field. The survey has made it very clear that the Nordic area has a relatively short tradition for permafrost-specific higher education. Even so, there is a strong focus on permafrost education throughout Norden, with a generally large component of active learning (e.g., field, laboratory, and computational work) in educational activities.

At present, five permafrost-specific courses are offered at Nordic universities, but only with a total capacity of around 100 students on an annual basis. All of these have been developed since 2005. The first permafrost-specific course AG-330/AG-830, which is also the most general permafrost course existing within geoscience, was established at UNIS in 2005, and has run since 2007, albeit not every year due to Covid-19 cancellations and staffing and economic challenges. UNIS so far has never run all four permafrost-specific courses in one study year, so the annual permafrost-specific course offering is more likely around 20 students at bachelor level and around 60 students primarily at master-student level. There is presently no single permafrost course specific to the PhD level in the Nordic area, but two MSc-level courses that are also open as a PhD study opportunity.

It seems logical that UNIS has the most permafrost-specific courses, both within geoscience and engineering, given its location in one of the few Nordic settlements built on permafrost. Both the AG-218 and AG-352 courses have been relatively recent expansions of the existing course curriculum within permafrost education. It, unfortunately, seems like UNIS will not be able to keep offering all permafrost courses, now that the AG-352 external project funding has ended. This means that UNIS will reduce the number of permafrost courses. UNIS, with its maximum of 20 students on all permafrost courses, due to field and laboratory activity, typically has long waiting lists of qualified students for these courses. This shows that many more students are interested in permafrost-specific studies. The SU-based permafrost-specific course GE7051, focusing on ecosystems and hydrology, soon will have run for 10 years, successfully attracting many international students including PhDs.

Located in a Nordic settlement built on permafrost terrain, the Arctic DTU campus in Sisimiut, West Greenland, has no permafrost-specific courses, but offers courses with significant permafrost-related content. Like UNIS, the relevant Arctic DTU courses also exploit the fact that they are taught directly in a permafrost environment. However, in contrast to UNIS, where most courses are open to international students on a course-by-course basis, two of the three courses with permafrost-related content (courses 12821 and 12831) at the Arctic DTU campus are available only to the students following the Arctic Civil Engineering programme and are taught primarily in Danish. This programme is a Professional Bachelor of Engineering, aimed directly at educating candidates for the industry. It was developed based on the CDIO (Conceive, Design, Implement, Operate) educational principle, and courses are therefore problem-based, multidisciplinary in nature, and focused on direct and active student engagement in all educational activities. Permafrost is taught in the engineering context in which it is relevant (e.g., site investigations, or road construction), along with the necessary tools to solve the relevant engineering issues, which are not only related to permafrost. Therefore, in the context of this survey, such courses figure as having minor (up to 30%; Table 2) permafrost-related content.

The survey has exposed an obvious difference in how the different Nordic countries have organised their higher permafrost education. UNIS is to some degree perceived as a national hub for permafrost education in Norway, while the situation for Denmark/Greenland is different. DTU has programmes with its Arctic DTU Campus in Greenland, while KU mainly has some field courses visiting Greenland. In Iceland, Finland, and Sweden the institutions typically teach permafrost topics making use of field sites/field stations away from their main campuses, but without any specific central institution addressing permafrost education. This probably to some degree reflects the geography of the Nordic region, with large parts of Greenland and Svalbard being remote to most people living in the Kingdoms of Denmark and Norway, while there is no such very distant Arctic area in Iceland, Finland, and Sweden. But this may also be due to the fact that, even though Norden includes vast Arctic and subarctic areas of permafrost, the population and universities are mostly centered outside of the permafrost zones. Permafrost may therefore be overlooked in some university educations, due to the perceived remoteness of permafrost areas and lack of relevance to local problems near the universities.

Permafrost education has been part of typical geoscience and engineering university courses for a long time, and more recently has also become part of ecology courses, as the focus on greenhouse gasses increase. This survey shows that permafrost content is part of many different subdisciplines, both within bio- and geoscience and engineering across the Nordic universities. And by far, most permafrost education is offered in these disciplines, typically as smaller parts (5-15%) for bachelor courses, and somewhat larger (10-40%) for master courses. However, only two such courses have been identified at PhD level.

With the increasing focus on climate change and its effects in the Arctic, several institutions identify their main permafrost educational aim to be for their students to understand the role of permafrost in the global biogeochemical cycle. This is primarily where permafrost is taught in ecological and biogeochemical courses. In geoscience-dominated courses the main educational aim focuses on periglacial landscape development, both presently but also in geological time, and mainly during the last interglacial the Holocene, with some permafrost modelling and remote sensing techniques. The engineering institutions aim for students to understand the principles of interaction between permafrost and built infrastructures, with a focus on the risks involved in construction on degrading permafrost.

Generally, there is an increasing focus on including more active learning into higher education (Biggs & Tang, 2011). The survey shows that permafrost education has a relatively good number of practical, active learning components. These consist mainly of problem-based learning, field excursions, fieldwork, laboratory work and computer-laboratory work (Supplementary Table A). In problem-based learning students are presented with specific problems and must find and learn the tools needed to solve these, assisted by the teacher. Many field activities take place during visits to field stations, in concentrated periods of time of otherwise classroom dominated courses. Also, some courses are short field courses, which in some cases explains the rather high proportion of fieldwork of up to 70%. This allows for performing the education in permafrost-relevant areas, as most institutions are not located on permafrost. It, however, also means that the field excursions and fieldwork are typically not reoccurring activities in the courses, which would improve the learning output (Biggs & Tang, 2011). Clearly, with the digital development a stronger focus on training the use of different technologies using computers is also increasing. And some courses now consist of up to 50% computer laboratories. It is interesting that typically most institutions probably still perceive the practical components largely as lecturer-led only, not including any details in the survey on the amount of direct student-led activities.

The Nordic staff responsible for permafrost educationrange from professors with a lot of teaching experience, to newly hired assistant professors with little teaching experience. Due to the wide range of different disciplines that have courses with permafrost components, it is also natural to have a high number of staff involved in teaching permafrost at each institution, with up to four staff members being listed as teachers.

5.2 Permafrost PhD courses are sparse

It is obvious that PhD courses within permafrost are very sparse in the entire Nordic area. Those existing are at a relatively general level, all taught together with a master course (UNIS courses AG-830, AT-801 and the SU course GE7051). This means that these three courses are primarily studied by PhD students, who typically did not study permafrost before in their education but are studying a PhD in which some basic permafrost knowledge is necessary, such as, e.g., in biogeochemistry in permafrost regions. This leaves Nordic PhD students studying permafrost with no specific course offering. This fact, together with the very clear identification of a need and wish for closer Nordic collaboration on permafrost education, is an important observation. This is interesting also as some joint activities were started during the IPY or shortly after, to increase particularly the PhD-level research-based education. However, this was dependent on separate project funding, as outlined in the historical review of permafrost higher education in this region. Probably the failure to continue these joint PhD courses may be attributed mainly to bureaucratic challenges regarding which institution(s) these courses should technically belong to, in combination with financial challenges of funding typically expensive field-course components. For some universities, such as SU and KU, the issue is also finding staff who have the time and are willing to teach this type of courses. This is so, as in these institutions teaching PhD courses is not included in the staffing system, and consequently must be done on top of all other teaching duties with no or only limited compensation. Therefore, to provide time for teaching PhD courses some type of external funding is needed, and its existence must be known well in advance for planning reasons (>1 year before the course is given). This experience clearly stresses the challenge of establishing joint educational activities within the Nordic area, particularly at the PhD course level. However, it might also be due to very little direct collaboration among the rather small permafrost higher educational environments within the individual institutions and even between the different Nordic countries. Understanding this situation is the way to improve it, which is why this mapping is necessary.

5.3 Developing higher permafrost education in Norden

Addressing the potential development of permafrost higher education, the bio- and geoscience survey replies are widespread, with priorities ranging from integrating permafrost into different environmental science courses, through integration between field observations, modelling, and remote sensing, to including more practical field and laboratory work and internships in permafrost education. Developing closer Nordic collaboration for different types of permafrost courses is an obvious need identified clearly by this survey. This will also be very natural as the Nordic area contains an environmental gradient allowing for studying all the different parts of the permafrost zones across this geographical region. Also, as the region contains the largest climatic gradient bridging the Fram Strait, from warm Svalbard to cold Northern Greenland, this allows for direct use of this gradient for permafrost educational use. With the increasing use of digital education, especially since Covid-19, potential is identified for building joint courses even within specific permafrost topics. Clearly, the mapped results provide the Nordic permafrost network with argumentation to do so and show the eagerness for doing this.

When it comes to increasing the practical components in permafrost higher education, the UArctic 'PermaIntern' joint Nordic network project is, during the period 2022-2024, designing and developing a first full-scale online permafrost internship service available to all interested students, universities, and internship hosts. Producing the best-educated candidates for societal needs requires focusing on the relevance of future working life. Importantly, internships should occur as early as possible and during the university education of a student. In Norway, this has been stressed in several recent white papers, such as Meld. St. 16 2016-2017 'Kultur for kvalitet i høyere utdanning', but recently also very directly in Meld. St. 16 2020 2021 'Utdanning for omstilling — Økt arbeidslivsrelevans i høyere utdanning'. Also in Norway, this is a very clear part of the ambition in the SFUs (Centre for Excellence in Education) *iEarth* and *bioCEED*, which are both focusing on further developing geo- and bioscience education adjusted to current and future societal needs.

The engineering institutions survey replies stress an urgent need for improving knowledge on how to respond to the ongoing ground warming in relation to societal infrastructure safety in permafrost environments. It is well-known that thawing of permafrost is a challenge for planning, construction, and maintenance of infrastructure development (Hjort et al., 2022). However, there is little engineering-specific undergraduate permafrost education and only with small capacity (max. 20 students on each course at UNIS). This means that most professionals don't know much about permafrost and thus how to mitigate the effects on it, or how to avoid sensitive terrain in a changing climate. In Alaska, professional engineers working in permafrost environments are required to have completed an 'Arctic Engineering' course, which is available in different formats, such as semester-based, intensive short course, and either in person or online (Stephani et al. 2022). Clearly, the Nordic region would also benefit a lot from having such a course offering in different formats. This would then ideally focus both on seasonal frost and permafrost to cover the diversity of frozen ground environments in Norden.

In Canada a MOOC (massive open online course) has recently been created by the Institut Nordiques du Quebec called 'Northern Quebec, Issues, Spaces and Cultures' (https://www.ulaval.ca/en/academics/mooc-massive-open-online-courses/northern-quebec-issues-spaces-and-cultures). The course covers a wide range of topics related to the Arctic and is given jointly by professors from different university departments of social and natural sciences. Such an overview-providing and interdisciplinary joint Nordic course might be useful to develop, with the aim of characterizing the region, and covering different topics including permafrost and seasonally frozen ground. This could then provide many more students in all types of science and engineering with a broader regional background and understanding of the diversity existing in the Nordic region, and potentially educate students from non-STEM studies, really expanding permafrost education more thematically in the universities.

Closely connected to the above discussed permafrost educational needs, the survey also identifies the need for developing an offer for further education allowing lifelong learning within permafrost topics. This is a direct need derived from the above outlined small number of permafrost courses. And there is also a strong political ambition in Norway clearly expressed in Meld. St. 16 2020 2021 'Utdanning for omstilling — Økt arbeidslivsrelevans i høyere utdanning' to develop lifelong learning, which this suggestion fits naturally into. Such learning for professionals should as a minimum provide education in basic permafrost concepts, in combination with providing space for exchange of practical experiences, hence including also practical, active learning components.

Hopefully, the collaboration that initiated the presented survey will lead to improved Nordic collaboration on permafrost higher education, and the curriculum mapping will act as a starting point. Our hope is that it will be possible to establish a Nordic online service as part of increased regional collaboration and as an important planning tool for future students when designing their permafrost education. Ideally this service will be closely linked with the internship service currently being developed, in addition to future further education within permafrost.

6 Conclusion

The presented basic curriculum survey of the Nordic permafrost higher education enables the following conclusions, listed in short form:

- Generally, the educational aims for permafrost higher education in Norden reflect that permafrost is part of the education within both bio- and geosciences and engineering, and there is variation in these educational activities. There is a strong focus on active learning in the mapped educational activities, with large field and laboratory learning components in most mapped courses, including computer-laboratory work.
- Five permafrost-specific geoscience and engineering permafrost courses exist, whereas there are 23 bachelor and 25 master courses with some permafrost content, for a total of 53 courses. The few specific courses are all relatively new, developed within the past 20 years. In Norway, there is some expectation for UNIS to offer specific and non-specific permafrost courses. In the rest of the Nordic area several institutions run permafrost-related courses in permafrost areas away from their main institutions, such as the DTU Arctic campus in Greenland. However, permafrost is taught in southern regions as well, under different formats and in a multidisciplinary framework, to make students aware of its existence and the related challenges in a context of climate change.
- The curriculum survey has led to increased collaboration and collegiality among the authors, clearly identifying the large potential and needs for closer permafrost teaching collaboration in Norden. This work shall focus on permafrost course development, teaching methods, and increased collegial sharing of practical experiences including fieldwork and active learning. This is an area that the Thematic Network on Permafrost (TNP) can address, and where online workshops/meetings can be starting points for further development. Such collaboration might establish:
    1. An online, potentially joint Nordic course on permafrost, in addition to the specific courses existing as mapped in this survey. This is probably best done

sharing the special permafrost competences existing across the universities. Making use of digital teaching tools will improve the chances of realizing this objective.

2. Nordic collaboration on developing joint, both general but also specific, PhD courses on permafrost. Presently, there is no offer for PhD students focusing specifically on permafrost in Norden. But several PhD students take master-level courses when needing to gain some basic permafrost training. Hitherto, specific PhD courses have only been given when additional (mainly Nordic) project funding was obtained.
3. Lifelong education in permafrost, particularly within engineering permafrost applications but also within other permafrost educational areas. This has the potential to contribute to better management of the current infrastructure, and more sustainable development of the future infrastructure and societies in the Nordic communities impacted by permafrost thawing.
4. Internships as a part of permafrost education to better meet the needs of future employers and society.

- There is a need to provide a public, online overview of all offered courses on permafrost – both specific and non-specific. This is also relevant, since the permafrost topic is wide-ranging from bio- and geosciences to engineering, and taught in rather small teaching environments at each institution. This paper represents an important first step, providing key details of all mentioned courses in the appendix.
- The Nordic region can benefit from establishing an overview-providing interdisciplinary joint Nordic course aiming to characterize the region and its diversity broadly, including both natural and social sciences, and covering different topics including permafrost and seasonally frozen ground. This will ensure that many more students in all types of science and engineering will have a broader regional background and understanding of the diversity existing in the Nordic region.
- The Nordic Master in Cold Climate Engineering is an excellent example of how a topic-specific educational collaboration across national borders in the Nordic region promotes the development of and accessibility to permafrost-related educational activities and courses aimed at an international student recruiting base.

The presented curriculum survey points to a need for increased educational cooperation for developing joint permafrost educational activities across the Nordic region. It seems harder to develop educational collaboration than joint research projects. The identified outcome of joint research-based permafrost education has proved possible in the form of joint PhD theses education. However, the present situation clearly identifies the need for increased direct deeper inter-university collaboration focusing even more on pedagogical development when potentially developing joint permafrost higher education both in the form of courses and other educational activities between institutions across Norden, and potentially with ambitions for joint permafrost degrees between several institutions. A natural next step in developing deeper collaboration will be to systematically share student reviews of all the mapped permafrost courses. Similarly, feedback from employers of permafrost students will be very valuable for increasing the work-related competencies required by future higher Nordic permafrost education.

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7 Supplementary material

Table A. *First Nordic university permafrost course catalogue, containing all details of all the courses mapped in this survey.*

Course name & institution	Level & % permafrost content	ECTS / duration of course and timing	Permafrost field components	Permafrost laboratory or other active components
AG-330/830 Permafrost and Periglacial Environments, UNIS	Master /PhD 100 %	10 / 5 weeks in spring semester	Excursions and fieldwork both lecturer and student led app. 20 %	Lab work lecturer/student led 10 %
AG-352 Geohazards and geotechnics of high Arctic permafrost regions, UNIS	Master 100%	10 /5 weeks in early summer	Excursions and fieldwork both lecturer and student led app. 35-40 %	Lab work lecturer/student led 10 %
AT-329 Cold Region Field Investigations, UNIS	Master 100%	10/ 5 weeks in spring semester	Lecturer led fieldwork app. 20 %	
AG-218 International Permafrost Bachelor Summer Field School, UNIS	Bachelor 100 %	10 / 5 weeks in early summer	Excursions and fieldwork mainly lecturer led, own project student led 30 %	Lecturer led lab work app. 5 %
AG-204 The Physical Geography of Svalbard, UNIS	Bachelor 10 %	15 / the autumn semester – run in combination with AG-221	Lecturer led fieldwork 2-5 %	
AG-221 Arctic Physical Geographical Field Techniques, UNIS	Bachelor 10 %	15 / the autumn semester – run in combination with AG-204		Lecturer led labwork 5 %
AT-205 Frozen ground engineering, UNIS	Bachelor 50%	15 / the spring semester	Lecturer led fieldwork 5 %	Lecturer led lab work app. 5%
AT-301/801 Arctic Infrastructure in a Changing Climate, UNIS	Master / phd 50 %	10 / 5 weeks in early autumn	Lecturer led fieldwork 10 %	

GE7051 Permafrost – Interactions with Ecosystems and Hydrology, SU	Master (/PhD) 100 %	7.5 / 5 weeks early in the spring semester	-	Lab work lecturer/student led 40%
GE7079 Polar and Alpine Environments and Climate Change, SU	Master 20%	15 / 9 weeks early in the autumn semester	Lecturer led excursion and own project, ~20 %	-
GE5035 Swedish Landscapes, SU	Bachelor 20%	2.5 / 2 weeks in late summer	Lecturer led excursion and own project, ~20 %	-
GE2021 Physical Geography, SU	Bachelor 6%	15 / 9 weeks in November-January	No	No
GE2028 Environmental Protection and Management, SU	Bachelor 2%	15 / 9 weeks in January-March	No	No
GE5037 Environmental Management Studies for the Biology Earth Sciences Programme, SU	Bachelor 2%	10 / 6 weeks in January-March	No	No
GE5033 Geomorphological Processes, Natural Hazards and Risk Assessments, SU	Bachelor 2%	15 / 9 weeks in November-January	No	No
GE2018 Geography I, SU	Bachelor 1%	30 / 18 weeks in the autumn semester	No	No
GE1021 Polar Environments, SU	Introductory 10%	7.5 / 9 weeks in the autumn semester	No	No
12821 Site Investigations DTU	Bachelor 15%	7.5 weeks, September-October		
12831 Constructions, DTU	Bachelor 10 %	6 weeks, August-September		Written essay including literature study, 5%

12854 Infrastructure Constructions in the Arctic, DTU	Master 30%	9 weeks, April-June	Lecturer led fieldwork 5 %	Lab work lecturer/student led 5-10 % Computerlab 5-10%
JAR107M Introduction to the Geology of Iceland, UI	Masters >5%	6 weeks in early autumn	5-day field excursion	NA
JAR617G Glacial Geology, UI	Bachelors >5%	Spring semester	5-day field excursion	NA
BA8622 Design of Roads and Railways in Cold Climate, NTNU	Master / PhD <5%	7.5/ 1 month of self-learning online modules followed by a 2 weeks intensive course/ fall semester		
1GE040 Glaciology and glacial processes, UU	Master 5%	15 /10 weeks	No	
1GE042 Geomorphology UU	Master 5%	10 / 7 weeks in later part of spring	No	Computer lab
1GE143 Landscape development, UU	Bachelor 5%	10 / 7 weeks in spring semester	No	Computer lab
1GV004 Planet Earth, UU	Bachelor 1%	30 / 20 weeks in fall semester and spring semester	No	No
NBIB14025U Basal arktisk biologi, KU	Bachelor <2%	7.5 / 9 weeks in spring semester	No	No
NIGB14035U Globale Geosystemer, KU	Bachelor <2%	7.5 / 9 weeks in fall semester	No	No
NGEA04066U Samfundsmæssigt væsentlige stofstrømme, KU	Bachelor <2%	7.5 / 9 weeks in fall semester	No	No
NBIK14001U Climate Change and Biogeochemical	Master 5 %	7.5 / 9 weeks in fall semester	No	Discussion exercise based on literature

Cycles, KU				
NIGK17013U Ecosystems, Climate and Climate Change, KU	Master 5-10%	7.5 / 9 weeks in fall semester	No	Exercise
NIGK21006U Aqueous Geochemistry, KU	Master 10 %	7.5 / 9 weeks in spring semester	No	Computer lab
NIGK15027U Surface Hydrology, KU	Master 12.5 %	7.5 / 9 weeks in spring semester	No	Computer lab
NIGK15006U Field and Methods Course in Geography and Geoinformatics, KU	Master Varying depending on teachers and student interest	15 / 18 weeks in summer and fall semesters. Offered every 2nd year in Greenland	Yes	Student-led project, including analysis of data collected in the field.
NIGK15005U Ecological Modelling, KU	Master < 5%	7.5 / 9 weeks in spring semester	No	Computer lab
NIGK13004U Climate Change: An Interdisciplinary Challenge, KU	Master < 5 %	15 / 18 weeks in fall semester	No	No
ECGS-035 Field Course on Arctic Ecosystems and Climate Change, UH	Master 50%	8/ one week in research station August, seminars at the universitys	yes	Some laboratory work at the field station
ECGS- 037 Seminar in Northern Ecosystems and Environment, UH	Master 20%	Spring term over four weeks, twice a week	no	no
ECGS-031 UH	Master 20%	Autumn term 6-week period, once a week	no	no
ECGS-601 Ecosystems and climate change, UH	Master 10%	Spring term, 6-week period, once a week	no	no
790102P Introduction to the Systematic	Bachelor 5%	5 / 4 weeks in spring semester	No	No

Physical Geography, UoO				
790329A Sustainability and Environmental Change, UoO	Bachelor 5%	5 / Late fall semester and spring semester	No	No
791624S Research of Northern Nature, UoO	Master 40%	5 / 2 weeks in fall semester	Lecturer led fieldwork 20 %	Computer lab 5%
791626S Methodological Special Themes in Physical Geography, UoO	Master 15%	5 / 3 weeks in spring semester	No	Computer lab 15%